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REFERENCE BOOK
ON
PRACTICAL COAL MINING

3RD EDITION.

Coal mining

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Yours truly,

W. WARDLE.

A COMPREHENSIVE

REFERENCE BOOK

ON

PRACTICAL COAL MINING

BY

W. WARDLE, F.S.Sc.,

MINING ENGINEER AND CERTIFICATED COLLIERY MANAGER.

UNIVERSITY OF CALIFORNIA.

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CALIFORNIA

PREFACE TO THIRD EDITION.

THE Author desires to acknowledge the favour with which two former editions of his *Reference Book* have been received. The work has now been thoroughly revised, and although, for the convenience of Teachers and Students who may already have adopted the work as a class text book, the numbering of the questions is kept uniform with that of the second edition, much new matter has been added; the answers being in many cases amplified and appendices inserted where desirable. The number of illustrative drawings is also increased. Valuable and willing assistance has again been rendered by Mining Engineers of eminence, and, in addition to acknowledgments in the text, the author desires specially to record the help afforded him by Mr. H. W. HUGHES, M.E., F.G.S., Mr. MILES SETTLE, M.E., Mr. GEORGE SPENCER, M.E., and Mr. HY. STOKER.

W. WARDLE.

West Cannock Collieries, Hednesford, Staff.,
June 1889.

PREFACE TO SECOND EDITION.

It is now about six years since I published my *Reference Book for Colliery Managers*, with the view of assisting those who might be desirous to pass examinations for certificates of competency. I endeavoured in that work to place within their reach essential information, in language as clear and concise as possible; and, as stated in the preface, my leading aim was to lay before mining students a work which, while assisting them to the knowledge necessary to fit them for the responsible charge of mining operations, should also be of permanent value to them and to all colliery managers. With this object constantly in view, I endeavoured to furnish good, simple, practical rules which science and experience have suggested for the solution of the perplexing problems and the making of the varied calculations with which the colliery manager has continually to deal.

The favour with which my effort was received—a new edition being called for—has induced me to greatly enlarge the volume. Additional matter has been inserted in every chapter, and two entirely new chapters have been written. The first edition contained 423 questions and answers; in the present edition the number has been nearly doubled. Especial care has also been taken to illustrate as fully as possible the questions discussed, and the drawings in the present volume are increased from 101 to 328. I venture, therefore, to offer this volume as practically a new work, and trust that in its enlarged form it will be of increased service to the mining community.

With reference to Chapter I.—Geology—the books that have been written on this subject are very numerous; the present work, therefore, attempts nothing more than to give a few of the principal matters concerning the relation of the science to coalmining. Chapter II. treats of Chemistry in a practical way, only so far as it applies to the gases met with in mines. In Chapter III. I have treated of Sinking, &c., in a manner which I think will prove most serviceable to the student and to the working manager, giving practical details in regard to the principal requirements of that branch of work. Chapter IV. is an entirely new chapter, and will, I trust, be found to contain useful information on the subject of Boring, Tunnelling, &c. Chapter V. Ventilation: In this chapter there are many rules and formulæ which will be found of great service. Chapter VI. Meteorology: The colliery manager and mining student will find in the remarks made under this heading much that will be both useful and suggestive—for rain and wind, and those changes in the atmospheric conditions which are indicated by the rise and fall of the barometer and thermometer, exercise an important influence on the roof and ventilation of the underground workings. Chapter VII.: The information contained in this chapter will help the student to form correct opinions in regard to Fuel, and it is really necessary that every student of colliery management should understand this subject. More information on this matter would greatly reduce, if it did not altogether put an end to the extravagant waste which daily takes place at many collieries. For much of the information on Safety Lamps, &c. (Chapter IX.), I am indebted to Mr. James Ashworth, who has placed his knowledge at my disposal, and also to Mr. Sawyer, her Majesty's Inspector of Mines, and to the Council of the North Staffordshire Institute. As regards the remaining chapters, nothing need be said in this place, save that in them, as in the whole of his book, the author has spared himself no pains to place before his readers as large an amount of sound practical information on the various subjects dealt with as the necessarily restricted limits of the work allow.

My mining experiences began at the age of eight years, in the pits of the Midland district, and since that age I have been constantly engaged in different capacities in mining operations. It is obvious, therefore, that this work can make no pretensions to literary excellence, but it is offered as a practical reference book on mining, written by a practical man.

In preparing this edition I have received valuable and willing assistance from mining and mechanical engineers of experience and standing, and, in order to make the work complete, I have not hesitated to quote freely from eminent writers on the most important mining topics.

Thanks are also due to several engineering firms for the loan of drawings, &c., of specialities manufactured by them, which it is hoped will add to the completeness of the book, and of which acknowledgment will be found in the text.

W. WARDLE.

Aldridge Collieries, near Walsall,
December 1886.

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REFERENCE BOOK.

CHAPTER I.

GEOLOGY.

1. What is geology ?

A science by the study of which we obtain a knowledge of the nature and position of the different masses of earthy or mineral matter, or rocks, and the mineral they contain.

2. Of what service is geology in mining ?

A knowledge of geology enables an opinion to be formed as to the existence of minerals and where they may be expected to be found.

3. What is the chief aim of the science ?

To enable us to recognise similar formations in distant localities, the varying nature of sedimentary deposits, the relations of the eruptive to the stratified rocks, and the laws regulating the direction, character and effects of faults, dykes and veins—these and many kindred problems can be solved only by a pretty extensive acquaintance with the facts and principles of geology.

4. What is coal ?

Coal is the product of the decomposition of vegetable matter, and is composed of those elements which enter into the composition of vegetable organisms, such as carbon, hydrogen and oxygen.

5. Are all rocks hard?

No; under the term rock the geologist includes all large masses of mineral matter, whether the constituent parts of such masses be agglutinated and strongly coherent or not. Thus, in this sense, loose sands and clay are rocks.

6. Is the earth everywhere composed of the same material?

No; the materials composing the earth vary considerably in different places. For instance, a shaft sunk in the neighbourhood of London, would first pass through clay, then a layer of sand, then flint and gravel; at Cambridge it would pass through a layer of chalk; at York, through a fine-grained sandstone; at Newcastle, through shale and coal; and in Forfarshire, through a red coarse-grained sandstone.

7. Were all the rocks formed at one period of time?

No. The various strata were formed at different periods; the chalk at Cambridge is older than the clay at London, the sandstone at York than the chalk, the coal of Newcastle than the sandstone, and the red sandstone of Forfarshire than the coal—that is to say, the coarse red sandstone was formed before the coal, and the fine-grained sandstone after the coal.

8. How far into the earth's crust are the rocks supposed to exist?

That is not known accurately; our knowledge of the crust of the earth only extends to—say, from 3,000 to 4,000 ft., but rocks are supposed to run to a much greater depth than this.

9. On what grounds do geologists base their supposition as to the depths to which rocks run?

By observing the increase of temperature in mines and deep wells. There is said to be an increase of temperature of 1 deg. Fahr. for every 60 ft. of descent or thereabouts; so it will follow that at a depth of $\frac{105,600}{3}$ ft. = $\frac{35,200}{1,760}$ yards = 20 miles, the increase of temperature would be 1,760 degs. Fahr., as $\frac{105,600}{60}$ = 1,760 degs. Fahr. At 50 miles the increased temperature would be 4,600 degs., more than a sufficient heat to melt any known mineral, as the heat of a common fire is 1,140 degs. Fahr., brass will melt at 1,860 degs., gold at 2,016, and platinum at 3,080.

10. What is supposed to be beneath the solid rocks?

A liquid or molton mass of metal.

11. Can this be definitely stated?

No; it is only supposition based upon observations of the increase of temperature in deep sinkings. No sinking has been carried so deep as to enable us to say certainly that the increase of temperature is constant.

12. What are the best means for arriving at a knowledge of the structure of the interior of the earth?

By excavations in deep drains, canal and railway cuttings, or pit sinkings; by a careful examination of clay, sandstone, coal, &c., we can form an idea under what different circumstances they have been formed.

13. How would you commence a surface examination in search of coal?

Before commencing an examination, it is advisable to procure any maps that may be in existence of the tract to be examined, and also of the adjoining lands. Although these may be imperfect in detail, and possess no high degree of accuracy, they will be serviceable in showing the location of streams, the ravines or valleys in which they flow, and the water-sheds. A pocket compass and clinometer are almost indispensable for taking the dip of the strata, &c., but a more convenient instrument for this purpose—the gradometer—has been patented by Mr. W. Fairley, mining engineer. The illustration (fig. 1) shows how it is used. When the edge, *g h*, of the instrument is laid on the plane, and is shown to be level by the spirit, *x*, there will be no inclination, but when the plane deviates from the horizontal line and the amount of the angle is required, the slide, *a b*, marked on one side by degrees and on the other by inches per yard, is taken out and passed through a slit, as shown by *e f*, which is simply the reverse side of *a b*. In the illustration the instrument shows the

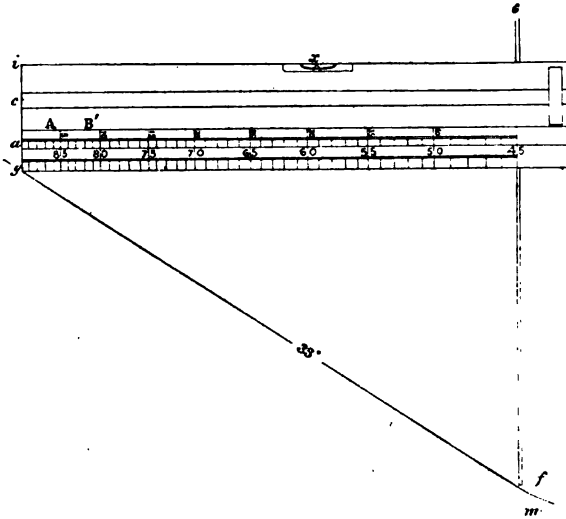

Fig 1.

plane, *g m*, to form an angle of 33 degs. or 22½ in. per yard, but any other angle may be measured. In measuring gradients or slopes above 45 degs. it is necessary to use the second slide, *c d*, by taking out and fixing the slide *a b* into the socket A B, then by moving the slide *c d* along the recess, it will indicate any angle required between 45 degs. and 90 degs. The slide *c d* is not brought into requisition so long as the angle is less than 45 degs. The 4 in. gradometer which is now being much used by colliery managers, bailiffs, overmen and viewers, is of less weight and more convenient than a clinometer of the same length, and shows the degrees with greater accuracy; for with the clinometer the arc is little more than an inch radius, showing the degrees in microscopical lines that can scarcely be read, whereas the gradometer of the size mentioned shows the degrees as plainly as a 12 in. protractor, in addition to the inches per yard, which are shown with mathematical nicety by dividing the length of the slide into exactly thirty-six aliquot parts. [The gradometer is manufactured by Messrs. John Davis and Son, of Derby.] Small excavations with pick and shovel may then be made along the stream bank or valley to find and expose the coal. Where the seams lie in the hills with a very slight dip, the position of a coal-bed is nearly always indicated by a spring of water loaded with iron, which is deposited upon the stones and vegetable matter over which the water flows. Having discovered a bed of coal, a small drift should be driven in a sufficient distance to fully expose its thickness, and to determine its quality and the character of its roof, floor and dip, the latter being ascertained by the use of the gradometer explained above. When ravines and valleys are filled with *débris*, and the banks thickly covered with detritus from the hills above, so that either no exposures are visible or nothing can be gained from an examination of them, it becomes necessary to rely upon topographical indications. The topographical features which denote the presence of a seam of coal are easily recognised. Most prominent is the bench or terrace which almost invariably occurs at the outcrop. When coal has been proved, or if the search has been thus far unsuccessful, a systematic series of trenchings may be undertaken. Operations are generally commenced some distance below the supposed position of the seam. Should the first trench prove unsuccessful, the same operation may be repeated at a higher and lower level on the hill side, and at some distance longitudinally from the first trench. The fact of finding no trace of coal in the loose drift overlying the strata is not conclusive evidence that coal is not present, for the soil in which the trench has been excavated may have been brought down from the hill above, and when this is probably the case each trench should be excavated to the strata.

14. With what minerals is coal generally found associated?

Coal is generally found in seams, separated one from another by strata more or less thick, such as sandstone, grit, shale, and hardened soils or clays, the whole being termed the coal measures of the carboniferous system. The seams are sometimes highly inclined, and in some cases are vertical or nearly so. Coal is found associated with ironstone, fireclay, &c.

15. Are all rocks minerals?

When two or more minerals occur together and form large masses they constitute rocks. By a mineral is meant any chemically homogeneous substance which neither forms nor retains any trace of having formed, part of an organised being, and which has not been produced by the application of physical forces by man.

16. What is a mineral vein or lode?

What a mineral vein is does not admit of an easy and strict definition. Dr. C. Le Neve Foster, in the course of a paper read before the Geological Section of the British Association, quoted briefly the definitions of a mineral vein given by Werner, Carne, Von Cotta, Grimm, Von Groddeck, Geikie, Sandberger and Serlo, who, in common with most geologists, have looked upon mineral veins as "the contents of fissures." While admitting that a very large number of veins may be so described, the writer of the paper contended that the exceptions are sufficiently important and numerous to warrant a change in the definition. He is of opinion that many of the principal and most productive tin-lodes in Cornwall are simply tabular masses of altered granite adjacent to fissures; and he brought forward the opinions of other geologists to show that certain veins in the English Lake district, the Tyrol, Nova Scotia, Nevada, Colorado, California and Australia are not filled-up fissures. In conclusion, he proposed the following definition:—"A mineral vein or lode is a tabular mineral mass formed more or less entirely subsequently to the enclosing rocks."

17. How are minerals distinguished?

Minerals are distinguished (1) by their physical peculiarities and (2) by their chemical composition.

18. How should a student proceed to acquire a knowledge of minerals for their identification?

He should familiarise himself with the general appearance of all minerals coming under his observation, and he should procure a collection of typical specimens of the more common minerals and rocks. Only by a careful study of specimens (object lessons, as it were) can any substantial knowledge of mineralogy be gained.

19. How would you distinguish a mineral by its colour?

The colour of a mineral may be either essential or non-essential. The essential colour is found by powdering the mineral; the powder thus obtained is called the streak. Although the non-essential colour may vary greatly, the streak is always uniform. A mineral thus shows its true colour when powdered.

20. How would you distinguish a mineral by its lustre?

The lustres of minerals are commonly either metallic or vitreous. The former is the lustre of all true metals, and nearly all minerals are composed of metallic elements. The vitreous lustre is the lustre of minerals in which the non-metallic elements preponderate, as in vitreous quartz. There are various other characteristic lustres, as adamantine, the lustre of the diamond; resinous, the lustre of resin; pearly, as talc, pearl spar; and silky, as satin spar. When lustre is entirely wanting, a mineral is said to be dull, as chalk and kaolin.

21. How would you distinguish a mineral by its hardness?

In minerals there are all degrees of hardness—from talc, which is impressible by the finger nail, to the diamond, the hardest of all known substances. To facilitate the determination of this characteristic, a scale of hardness has been devised as follows, beginning with the softest:—

1. Talc.
2. Gypsum.
3. Calcite.
4. Fluorite.
5. Apatite.
6. Orthoclase.
7. Quartz.
8. Beryl or Topaz.
9. Corundum.
10. Diamond.

Of any two minerals, that which scratches the other is the harder, and by testing an unknown mineral by those given in this scale, its degree of hardness can be ascertained. For instance, a specimen that will scratch calcite, but is in turn scratched by apatite, would be estimated for hardness at 4, but should it also be scratched by fluorite its place would be 3·5.

22. How would you distinguish a mineral by its weight?

The specific gravity or weight of minerals is one of the most constant characteristics. It is more difficult to discover, however, than hardness; and is, therefore, less practised. If the specimen is not too small, its weight can generally be estimated with sufficient accuracy for practical purposes by lifting it in the hand.

23. How are minerals distinguished by the forms of their crystals?

Though many minerals occur in an amorphous or massive state, others occur in distinctly-formed crystals—that is, in figures bounded by plane surfaces arranged regularly about a centre. Minerals of the same class always crystallise in similar or allied shapes. The determination, therefore, of the crystallised form is an important aid in identification. For instance, iron pyrites commonly crystallises in tubes, and is so distinguished from copper pyrites, which it somewhat resembles. Tourmaline and hornblende, when occurring in small fragments in rocks, are very similar in appearance, but the tourmaline can easily be distinguished by its long, slender, triangular crystals. In order to recognise any but the simpler forms of crystals, a knowledge of crystallography, the science which treats of the forms resulting from crystallisation, is necessary, but as minerals commonly occur uncrystallised, we are often obliged to depend upon other characteristics, and the determination of the crystallographic form is seldom absolutely necessary.

24. How would you distinguish a mineral by its cleavage?

Cleavage, or the tendency of a mineral to split along certain planes, is a property closely allied to the crystallised form, and is frequently useful in the identification of minerals. Common feldspar (orthoclase) can be distinguished from similar minerals by its splitting or cleaving in certain directions with a bright even surface.

25. In what other forms do minerals occur?

When a mineral does not occur, as is commonly the case, in distinct crystals, its general structure should be noted, whether it consists of an aggregate of fine grains like granular quartz, or forms a compact mass like flint or chalcedony. Notice if it is made up of a number of slender columns like some tourmaline, or of fine fibres like asbestos or satin spar. Sometimes a mineral has a laminar structure, consisting of a succession of plates or leaves, like common mica. Again, it may be found in globular forms like marcasite (white iron pyrites), or in a shape resembling a bunch of grapes, termed botryoidal, like limonite or chalcedony. Minerals also occur in coralloidal (coral-like) forms, as argonite, or dendritic (tree-like) shapes, as magnetite (magnetite iron ore). Others occur as stalactites or stalagmites, as limestone. A careful examination of the general structure and imitative shape, if any, of a mineral, will often lead to its identification without any further trouble.

26. Can the characteristics of minerals be determined by any other physical tests than those given above?

Yes; there are various other physical tests for minerals, such as magnetism, taste, odour, feel, tenacity and phosphorescence. These are often useful in classifying. For instance, magnetite can be distinguished from minerals which it otherwise resembles by its property of being attracted by a magnet; native alum by its astringent taste; kaolin or clay by its peculiar odour; and the hydrous silicates—talc, serpentine and chlorite—by their smooth or greasy feel. When two pieces of quartz are rubbed against each other they emit light, or are phosphorescent. The determination of their physical characteristic is, generally speaking, sufficient to identify all common and many uncommon minerals, but others need to be tested chemically before their identification is rendered certain.

27. How are the characteristics of minerals determined by chemical tests?

Treating the mineral with acid is usually the first step. Calcite or common limestone can be readily recognised by its lively effervescence when touched with hydrochloric (muriatic) acid while in the mass, but dolomite or magnesian limestone will only effervesce when powdered. Other minerals require the use of strong or hot acid. In addition to hydrochloric, sulphuric and nitric acids are often used. By the employment of acids the degree of solubility is determined, the presence of carbonic acid detected and various other results obtained. After treatment with acids, come the blow-pipe tests. The mineral is placed upon charcoal and submitted to the action of the flame of an alcohol lamp or gas jet directed upon it by the blow-pipe. The degree of fusibility, the colour of the flame, the character of the sublimates, and the odour of the escaping gases are noted. The mineral is heated in open and closed glass tubes, and then mixed with the fluxes, borax and salt of phosphorus. By these and other methods of treatment, and by reference to a set of tables on the classification of minerals, the exact status of the specimen in hand is finally decided.

28. Give your views in short on the formation of the rock-salt beds.

It is supposed that rock-salt beds have been formed by water impregnated with minerals flowing through a cleft or channel into a basin or lowland, to which there was no outlet, the minerals being deposited at the bottom of the basin, and evaporation proceeding so rapidly that the water still flowed in, until the basin or lowland was filled to the level of the cleft or channel with the deposited minerals. This theory is borne out by the fact that rock-salt is generally found in basins—that is, thinning out wedge-like in every direction.

29. What are the composition and characteristics of pyrites?

Pyrites or sulphide of iron is composed of about fifty-three parts sulphur to forty-seven iron. It is a pale, sometimes bright yellow mineral, nearly as hard as quartz and about twice as heavy. It can be but slightly scratched by the knife, is always opaque, somewhat brittle, and strikes fire readily with steel. To this latter quality it owes its name, which is derived from a Greek word for fire. There are two forms of pyrites—pyrites proper and the rhombic variety called marcasite. The latter is far more susceptible to decomposition than the ordinary (cubic) variety. Marcasite is a little paler in colour and inferior in specific gravity. Some coal seams containing large quantities of pyrites are not liable to spontaneous combustion—for example, the South Staffordshire stinking coal. No doubt pyrites plays a very small part in the spontaneous combustion of coal, but it does something. Mr. H. W. Hughes, F. G. S., contended, in a paper he read before the South Staffordshire Institute of Mining Engineers, on "Spontaneous Combustion," that it really is the rhombic variety of pyrites (marcasite) that does mischief, and that when the cubic variety of pyrites is present little danger may be apprehended. The symbol for both forms is the same—FeS_2

30. Is pyrites worked separately for the material itself?

No; although pyrites contains 50 per cent. of iron, it is never worked for that metal, which can be obtained much more cheaply and easily from other ores. Sulphur is sometimes obtained from the pyrites, but its principal use is in the manufacture of copperas and sulphuric acid. It has not been mined to any great extent in this country as yet for these purposes, though largely used in England. Though pyrites occurs almost everywhere, there are certain localities that afford unusually fine specimens.

31. How is pyrites affected by exposure to the atmosphere?

Pyrites is one of the most changeable of minerals. When exposed to the action of the weather for a length of time, as when picked out from the coal on the pit-bank, or as at the outcrop of a vein, it loses considerably in weight, and in its decomposition loses its yellow colour, becoming of a rusty iron hue, changing into iron oxide. This rusty honeycombed appearance of much gold-bearing quartz is due to the decomposition of the pyrites. The liability to decomposition renders all rocks containing much of this mineral unfit for building purposes where beauty and durability are desired. Pyrites has often been mistaken for gold, owing to its yellow colour, and much money has at one time and another been wasted in consequence. Gold is, however, very easily distinguishable from pyrites—indeed, the only resemblance lies in the similarity of colour. Gold is a soft mineral easily cut with a knife, is of a deep yellow colour, and is nearly five times heavier than pyrites. Gold is malleable, pyrites not. As, however, a small proportion of gold is often present in pyrites, it is always well to ascertain by analysis whether it will pay to work that metal.

32. Where is pyrites generally found?

More or less in every coal seam, and some seams afford unusually fine specimens—the New Mine and Stinking coal of South Staffordshire, for instance. Pyrites very commonly occurs in quartz veins with various metallic ores, and is almost invariably found in gold-bearing quartz, intermingled with the precious metal. When gold is disseminated through the pyrites, it is then called auriferous or gold-bearing pyrites. A considerable proportion of the yield of gold is obtained from this variety.

33. Can minerals be separated one from the other by washing in water, when after washing all are of one specific gravity?

No; where there are two minerals of equal size and specific gravity, a separation cannot be made by such means. In separating various ores from each other and from the adhering gangues by means of water, it is their specific gravity when reduced to equal sizes that causes their final separation, for when subjected to a current of water upon an inclined plane, the heavier substances will be deposited at its top, and those of less specific gravity will be swept away; or when dropped in a column of water, the heavier material will fall first to the bottom, while the lighter mineral is held in suspension for a longer time and settles down more slowly. But when the two substances are of equal size and specific weight, they will move with equal speed, and separation cannot take place. This happens, for instance, with the sulphide of zinc or blende, and with the sulphide of iron or iron pyrites, both of which have about the same specific gravity.

34. What is your opinion as to the origin of petroleum oil?

Scientific men do by no means agree as to the origin of petroleum. In the early history of American oil mining, the only question much debated was whether it was of animal or vegetable origin—or both. Of late, however, a theory has been started that the oil is due to chemical combinations of carbon and hydrogen in the interior of the earth, and this view is supported by the fact that petroleum has been found in such large quantities as almost to preclude the possibility of the older hypothesis.

35. How are rocks classified?

Into three great divisions—aqueous, igneous and metamorphic. Under one or other of these heads all rocks may be arranged, according to the agency by which they have been brought into their present state.

36. What is understood by the term "aqueous" rocks?

"Aqueous" rocks are those that have been formed by the agency of water, from the *débris* of the igneous rocks. In their formation, chemical, mechanical or organic causes may have operated.

37. What is understood by the term "igneous" rocks?

"Igneous" rocks are rocks formed under the agency of fire. They are made up of minerals that are silicates. These minerals may be divided into two great classes—namely, silicates of magnesia and silicates of alumina. The igneous rocks have also been classed, according to their age, as granite, trappean and volcanic.

38. What is understood by the term "metamorphic" rocks?

"Metamorphic" rocks are sedimentary rocks which have undergone, at a great depth beneath the surface, the process of change called metamorphism, by which their constituent elements have been re-arranged, and generally a crystalline texture produced.

39. What steps does the geologist first take to determine the class to which rocks belong?

The first step would be to chip or scratch with a pocket knife or other instrument to fresh surfaces at right angles to each other for the purpose of ascertaining the texture. If the rock be a compact one—that is, if no crystals or grains are visible with the lens—if it is easily scratched with the point of the knife, it may be inferred that it is either an aqueous rock or a very much decomposed igneous one. A little dilute acid may next be applied, and if it effervesce freely it may be pronounced limestone; but if slowly, the rock may be magnesian limestone; if the acid takes no effect it may be either gypsum or a decomposed rock. If a considerable force is required to scratch the rock it is probably a compact igneous rock; if no scratch is made, but the rock is merely marked, it is probably a purely siliceous rock, such as flint, chert, &c., and, therefore, of aqueous origin.

40. Under what head do the rocks termed stratified rocks come?

Stratified rocks come under the head of aqueous rocks.

41. To what period do the coal measures belong?

Practically the carboniferous period, so called on account of the abundant coal deposits. Coal is, however, found in several parts of the world associated with rocks of different periods. The carboniferous system consists of aqueous or stratified rocks, and includes seams of coal, clay, bands of ironstone, beds of shale, &c.

42. What term should be used in classifying loose sands and clay?

They should be considered "rock," under which head geologists include all large masses of mineral matter, whether the constituent parts of such masses be agglutinated and strongly coherent or not.

43. In a lease of "all the mines and minerals under an estate," would you consider any surface clay or sand-bed on the same estate included?

Yes, if not definitely stated otherwise, and the holder of the lease will have a just and lawful right to get or remove the same if "all minerals" is expressed in the lease.

44. A railway or canal company refuses to buy the mines and minerals over which their railway or canal has to pass. Would a mining company be liable for damage done to the said railway or canal by their mining operations or by removing any beds of clay at the surface?

Not if legal notice is given to the railway or canal company of intention to work the said minerals under their property, unless the railway or canal company make a compromise to pay a "just" value for the said minerals left to support their railway or canal.

45. What does the term clay include?

The term clay in mining covers many varieties, as any very finely-divided mineral matter which contains from 10 to 30 per cent. of alumina, and is consequently plastic or capable of retaining its shape on being moulded and pressed, would be called clay. There are many varieties of clay; the following are the principal:—Pipeclay, free from iron; fireclay, nearly or quite free from iron and lime; shale, regularly laminated "clay," more or less indurated, and splitting into thin layers along the original planes of deposition of the rock. The colliers' terms for shale are bind, bluebind, metal, plate, &c. In South Staffordshire the term "batt" is commonly applied to a lump of shale, and sandy shales they term "rock binds." Clunch is a common name in South Staffordshire for a tough, more or less indurated clay. Marl is properly calcareous clay. Many clays, however, are commonly but erroneously called marls. Shell marl is the marl found at the bottom of an old pond or lake, obviously formed from the decomposition of shells. Loam is a soft and pliable mixture of clay and sand, enough of the latter being present for the mass to be permeable by water and to have no plasticity. Argillaceous flagstone is an indurated sandy clay or clayey sandstone. Clay slate is a metamorphosed clay differing from shale in having a superinduced tendency to split into thin plates. Mud and silt are the incoherent and quite unconsolidated materials of some form of argillaceous rock, either clay, shale, loam or marl, according to circumstances. Clay rock is a name that is sometimes used to designate a highly-indurated mass of pure clay, not soft enough to be plastic without grinding and mixing in water, and as beds of clay both underlie and overlie most seams of coal, &c., and occur at all depths, this clay, whether at the surface or deep in the earth, is included in the term mines and minerals just as correctly as a seam of coal itself.

46. Give a short description of clay ironstone.

Clay ironstone is a dull brown or black compact form of siderite with a variable mixture of clay, and generally also organic matter. It is found in the carboniferous and other formations either in the form of nodules (where it has usually been deposited around some organic centre) or of beds interstratified with shales and coals.

47. Has coal been found underneath the chalk in any other part of Europe besides Prussia?

Yes; the northern coalfield of France is everywhere covered with strata of recent formation (called in French *morts terrains*). Below these come tertiary strata very like the plastic clay found under the London clay, and finally strata of the cretaceous formation are passed through before coal measures are reached. (I am indebted for this answer to Mr. H. W. Hughes, F.G.S., Dudley.)

48. Give your views of the origin of coal.

There is little doubt now in the minds of geologists that coal was at one time on the surface, in the shape of dense forests, with an undergrowth of ferns and mosses, and vast swamps in which a few lizards and fish lived. These forests were distinguished by a rank vegetation allied to the ferns and club-mosses of the present day. The process of growth and decay must have been very rapid in that age, and beds of peat were formed (found in great abundance at Rainford and known as "moss.") Thus growth and decay went on for a long series of years, being followed by subsidence or sinking down of the ground, and allowing the bed of vegetable matter to be covered with some earthy substance, very likely a kind of clay deposited from water. Under such circumstances fermentation must have taken place in the vegetable mass, its heat became raised, and a re-arrangement of its constituents resulted. We may suppose this series of processes to have been repeated many times, for we find seam above seam of coal, each seam produced by a period of growth and then a period of subsidence.

49. Can you give a further explanation why coal is supposed to be of vegetable origin ?

Yes ; we find in the coal measures—as the beds of coal and the intervening shales and sandstones are termed—enough of the remains of the ancient plants to be able to recognise, with some degree of certainty, the forests of the coal period. They contained trees with vast naked trunks marked with regular patterns (the marks of the leaves of former years) crowned with a plume of fern-like or palm-like leaves; large trees with branches without distinct leaves, but covered to the tips of the smallest twigs with scales like club-mosses, that now grow on our mountain sides ; gigantic equisetums or horse-tails ; also some trees of a similar structure to our cone-bearing trees, the firs and the junipers, but the greater part were of a kind which grew fast and died fast.

50. Can you give any estimate of the time which has elapsed since the British coalfield existed as forest ?

No accurate estimate can be made. It has been conjectured that a period of at least a thousand years must intervene before vegetable matter could accumulate to form a bed of coal one yard thick. In South Staffordshire some seams of coal are ten yards thick, so this will represent a period of ten thousand years during which the peat accumulated to form this seam of coal.

51. At what rate are sedimentary strata formed ?

It is conjectured that sedimentary deposits will form at the rate of two feet in a century, and at this rate a period of 3,807,000 years must have elapsed to form the South Wales coalfield.

52. If the old red sandstone be found at the surface, and is largely developed in a district, is coal likely to be found there?

No; because as this formation lies below the carboniferous, or great coal-bearing strata, it would be useless to search for coal there under such conditions.

53. If chalk be found at the surface, does that preclude the possibility of finding coal beneath?

By no means, for coal has been found beneath the chalk in Prussia.

54. Of what use or service is the knowledge of fossils to geology?

As each geological formation has its peculiar fossils, a knowledge of them frequently enables us to determine the formation, when we might not otherwise be able to do so.

55. If in sinking a pit you meet with a fossil plant called *Walchia piniformis*, what conclusion would you come to?

As this plant is characteristic of the permian, I should conclude we were working in that system.

56. What other kind of fossils are usually found in the coal measures?

The fossils which are found embedded in the variously constituted strata are known to be chiefly marine, and sometimes such as live in fresh water, partly because some of them are identical with living species.

57. In what measures are the fossils called stigmaria and sigillaria found?

Generally, the fossil sigillaria is found embedded in the coal measures; sometimes standing erect as the tree grew, with its roots, stigmaria, embedded in the under-clay of the seam of coal. At the present time there is a very fine specimen to be seen at No. 2 Pit, Aldridge Colliery (fig. 2). The fossil tree when found was standing erect as the tree grew, or nearly so, the base of fossil being partially embedded in the coal seam, with its roots (stigmaria)—which are composed of shale—passing through the seam of coal into the underclay; the stem of the fossil is over 3 ft. in diameter, and the heart of it is composed of very strong shale, covered with a coally coating or bark of coal about

¾ in. thick. It will also be partly seen from sketch that the fossil was found between two faults, which necessitated the "ripping" or breaking down the roof for 16 ft. so as to work the seam of coal on the opposite side of the fault, and

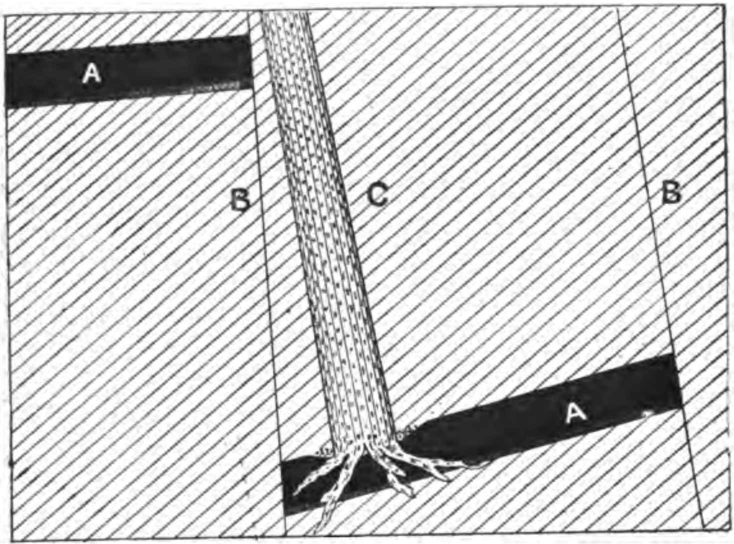

Fig. 2.

at this height there is no indication of the top of the trunk. Sir Charles Lyell mentions a specimen 72 ft. in length found at Newcastle.

58. How are fossils polished?

Thoroughly clean the specimens first, then coat them over with pure shellac varnish, afterwards place them in an earthenware vessel to dry.

59. Give a short description of the origin of limestone?

Limestone is chiefly formed by the agency of small marine creatures of low organisation. By them the carbonate of lime is recovered from the ocean, and at their death the harder parts of their structure falling to the bottom, accumulate as a mass of pure limestone, which con-

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solidates into limestone rock. The limestone itself will afford some information as to the circumstances of its deposition. Where, as is often the case, the limestone occurs hundreds of feet thick, and composed of little else than carbonate of lime, we know that it was formed, far out at sea, in the clear waters of mid-ocean; where the limestone grows in certain directions earthy and impure, and layers of shale and sandstone, thin at first, but gradually thickening out in a wedge-like form, occur between its beds, we may judge that in those directions we are travelling toward the shore lines of the sea whence the water was receiving supplies of muddy and sandy sediment.

60. Give a short description of the formation of sandstone.

Sandstone consists simply of grains of sand bound together by a cementing material. It consists sometimes of pure silica, but usually is a mixture of sandy, clayey and other substances. Sometimes clay is mixed with sand and other substances, forming a conglomerate. Rivers are constantly carrying sand and mud down to the sea or to the lakes into which they flow, and when their flow is slackened on entering the still water, the material brought down with them sinks, and is deposited in layers over the bottom. The structure of sandstone shows that it has been formed in this way; and the remains of plants which have been carried down by the stream, and occasionally of the animals which lived in the water, are found embedded in the deposits.

61. What is meant by a fault?

By the term fault is understood an interruption of the continuity of a stratum. Interruption may be complete or only partial, and it may have been produced by one of a multitude of causes. These fractures are called faults or dislocations by geologists, miners in different districts using other expressions to signify the same thing—as slip, slide, heave, dyke, thing, throw, trouble, check, swell-roll and horse-back. The amount of dislocation measured in a vertical direction produced by a fault is called its throw, a fault being said to be an up-throw or a down-throw, or an upcast or downcast, according to the side from which we view it.

62. What is a dyke?

A dyke is an intrusive band or seam of hard rock, usually of igneous origin. A fault is often erroneously called a dyke. Dykes are seldom accompanied by a dislocation of adjacent strata; they owe their origin to some deep-seated connection with the molten interior of the earth, out of which they have doubtless been ejected in the shape of lava, and are of a period much lower and of earlier date than the carboniferous. Belts of igneous rock may be seen in different parts of the South Staffordshire coalfield dividing the coal measures, the measures on either side not being disturbed. In one case I have seen, at the Walsall Wood Colliery, a belt of igneous rock divides the seam of coal and strata above it and below, and neither the seam of coal nor strata are disturbed, though the coal is calcined or blackened for some little distance, showing that the igneous rock had come from a lower period than that in which it was found. When, therefore, we take into account the absence of animal or vegetable remains in the rock, and that the properties of it mainly consist of felspar and hornblende, we can come to no other conclusion as to its origin than that stated.

63. What terms are used to describe igneous rocks in South Staffordshire?

Basalt, greenstone, trap, white rock trap, white felspathic rock, white horse, green rock and Rowley rag, are the terms usually applied to igneous rocks in the South Staffordshire district.

64. Give a sketch of a fault and the method usually adopted in measuring the amount of throw?

If, for instance, a bed of coal, where it is cut by a fault (fig. 3, A), be 100 yards from the surface, or from an assumed horizontal stratum line, A B, and the other part of the bed immediately on the other side of the fault, as at B, be 200 yards below the line A B, the throw of the fault is said to be 100 yards, without regard to the distance measured laterally from A to B along the surface, or from A to B along the fault. In some places, especially in cases where the outcrop of a bed is dislocated at the surface, the distance, A B, by which the ends of the beds are separated is called the "heave" of the fault, though this is sometimes measured along the fault from A to B. In taking accounts from miners as to the character of faults, it is necessary to be on one's guard, and be quite sure that the sense in which they use these terms is properly understood. In some districts they would speak of the distance A B measured along the surface of the ground, or the horizontal distance between the ends of the beds as the "width" of the fault, looking only to the extent of "barren ground" as to that particular bed, and paying no attention to the real width of the actual fissure itself, which might not be more than a few inches, or perhaps even not more than one.

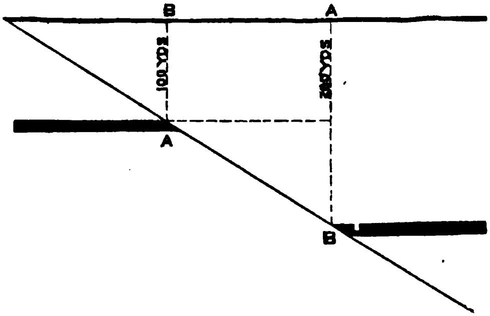

Fig. 3.

65. Give a sketch of a fault where both the seam of coal and rocks under and overlying it have been disturbed?

Fig. 4 is such a sketch, the layers being numbered according to their corresponding strata on the opposite side of the fault.

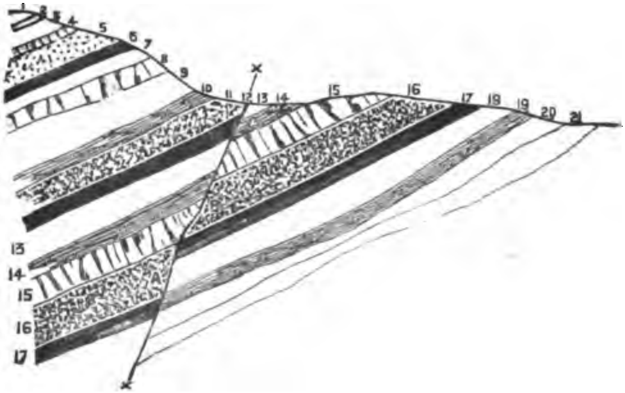

Fig. 4.

66. Give your views on surface springs or feeders.

Surface feeders have direct communication with the earth's surface, and must therefore vary with wet and dry weather, and the varieties of the seasons. Partial feeders are such as gradually decrease after being opened, and in time are entirely exhausted. Permanent feeders may continue for many years, with but little diminution, finding their way through interstices in the strata for considerable distances, which troubles the sinking until a good firm stone is met with which is, or may be, impervious to water. Some strata hold more water than others, because more porous, and act as does a sponge. Other strata are too hard and compact to be permeated by water. As to the depth at which salt water may be found, I think there is no limit, or how could we have salt water springs at the surface? The following diagram (fig. 5) is an ideal section, which shows how a spring may occur, and also how water may impregnate one stratum more than another.

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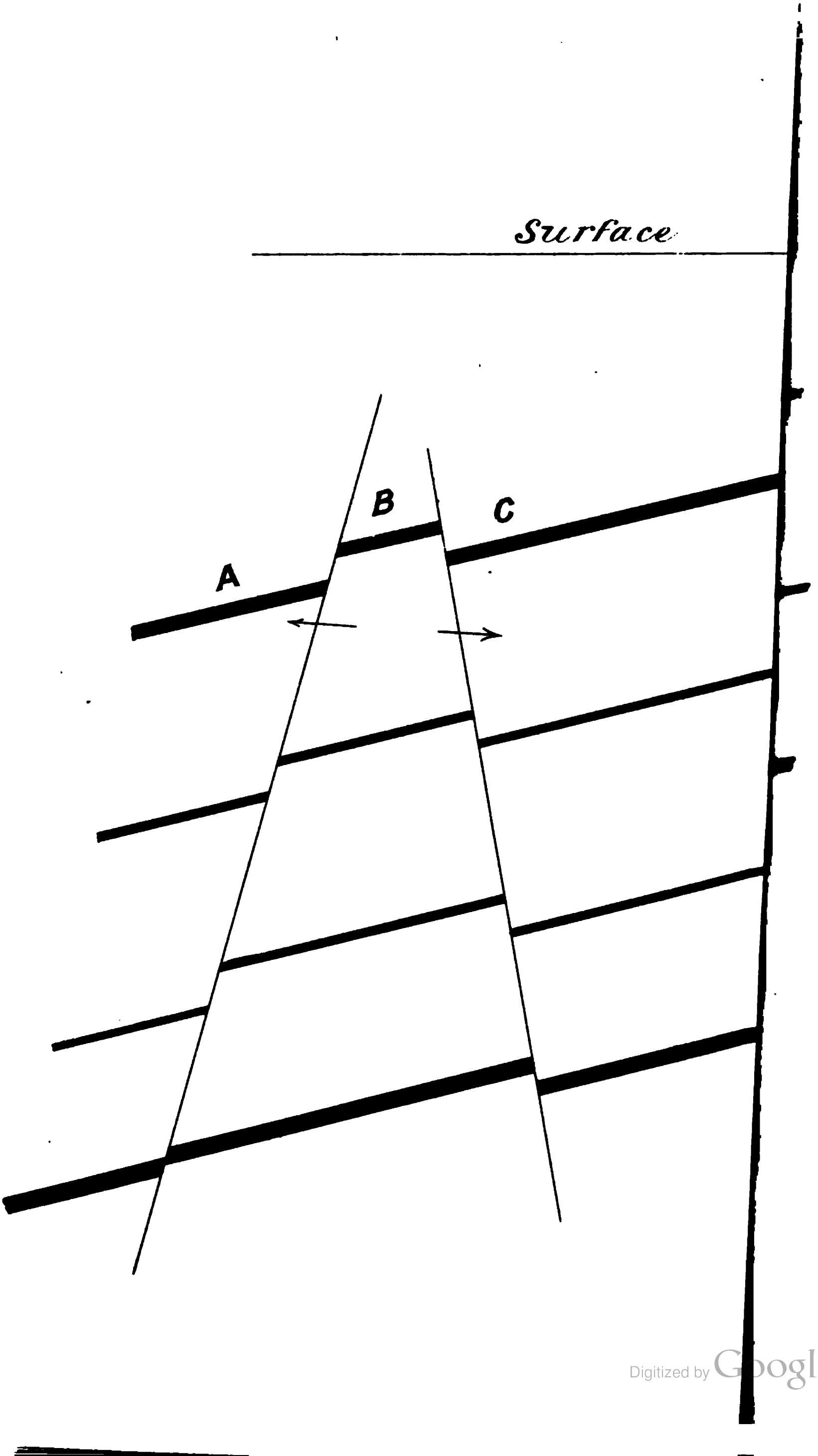
Surface
B
C
A

The water makes its way down the inclined strata.

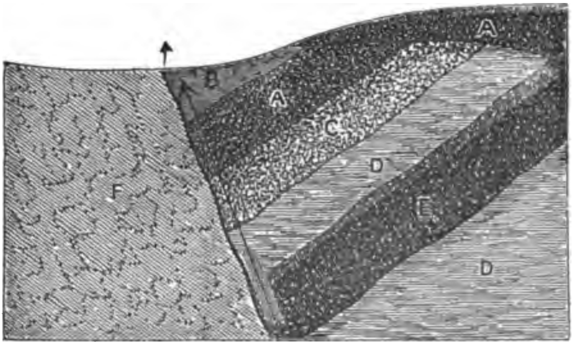

Fig. 5.

References.—A, sand. B, soil. C, gravel. D, clay or impervious strata. E, sand or some pervious strata. F, impervious strata.

67. What is meant when we speak of faults having a parallel strike?

When two wedge-shaped portions of strata increase in thickness downwards, and the dip of the throws are in opposite directions, leaving the centre portion higher than the two outer portions, as shown on fig. 6, A B C, or when the contrary is the case—namely, two throws leave the centre portion lower than the two outer portions, as shown on fig. 6, D E F.

68. What is meant by a branch fault?

The term is used when one or more faults strike out from the main fault at a junction, as at G (fig. 6). Branch faults usually dip in the same direction as the main fault; when the branch fault dips in an opposite direction to the main fault, it is generally found that the throw of the branch fault increases the further it is removed from the main fault, showing it to be a branch out of the main fault in another part of the coalfield, or, in other words, it is a branch fault out of the east main up-throw fault, running across the coalfield until it strikes the west main up-throw fault. These are termed interrupted faults.

69. What is meant by a cross-fault?

When one fault crosses another, it is termed a cross-fault. Where a cross-fault occurs, we are led to the conclusion that the faults are of different ages, the younger fault being continued uninterruptedly, and separating the older fault in two parts, and the older fault still retaining its original striking dip, the strata is divided into four parts by the two faults.

70. Give some of the varieties of faults?

Faults vary in character and in effect—firstly, according to the nature of the rocks which they traverse, whether they be hard or soft, or an alternation of both; secondly, according to the position of the beds which they traverse, whether these be horizontal, inclined or contorted; thirdly, according to the direction and number of lines of fracture, their inclination and combination.

71. Give a section of a coalfield that you are acquainted with which is traversed by a large fault.

See fig. 7, which is a correct section of Bank Top Colliery, Burslem. It will be seen there has been an eruption, termed fault, which has removed the seams of coal, &c., 95 yards higher on the one side of the fault than the corresponding seams on the opposite side. The No. 2 pit is sunk down to the Burnwood seams of coal and ironstone; but, to work the same seams on the opposite side of the fault, a new pit would require sinking or a horizontal tunnel driving at A, 260 yards long; and to work the Rowhurst coals from the mouthing made in the Burnwood seams, a tunnel would require to be driven at B, 180 yards long.

72. Can you illustrate a section of a coalfield which is much broken up by faults?

Yes; fig. 6 is a section of part of a coalfield that I am acquainted with, with all the details of tunnelling, &c., for winning the coals through the faults.

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73. What is meant by conformable and unconformable strata?

Strata which have been deposited continuously and without disturbance upon other strata are said to be conformable. If, on the other hand, the strata rest on a series of rocks lying at a different angle—which may be horizontal, inclined or contorted—and with which they have no direct connection, they are said to be unconformable.

74. What is understood by the terms dip, strike, basin, outcrop?

Dip is the direction in which the stratified measures fall, and is at right angles to the strike; the basin is the centre of a coalfield where the seams rise in every direction from it; the outcrop is where the seams come out to the surface. The student who desires to obtain a good knowledge of geology should systematically examine all quarries, railway cuttings, sinkings, &c., within his reach, as well as study thoroughly some of the standard works on geology, such as Geikie's *Text Book of Geology.*

APPENDICES TO CHAPTER I.

DESCRIPTION OF THE COALFIELDS OF GREAT BRITAIN.

The following is a brief description of the coalfields of Great Britain and Ireland, in the preparation of which the author has been greatly indebted to the records of the various geological surveys, as well as to the several gentlemen referred to in the text:—

Devon and Cornwall.—This district bears a certain resemblance to the county Cork. Probably a large part of the slates, called killas, are of the age of the Old Red Sandstone, and they are so coloured in all later geological maps. Above these lie a series of slates containing carboniferous plants and beds of culm, with bands of limestone here and there in the lower strata. This limestone contains *Posidonomya* and other fossils, from which it has been classed with the carboniferous limestone, and beds of sandstone above it are supposed to represent the millstone grit. Possibly the culm measures of Devon may turn out to be the representatives of the lower coal measures only, resting, perhaps, unconformably on the carboniferous slate rocks.

South Wales, Forest of Dean and Bristol.—A general description of the formation in this field is as follows, assigning the maximum thickness to each group :—

4. Coal measures	7,000 to 12,000 ft.
3. Millstone Grit, or Farewell Rock	1,000
2. Carboniferous Limestone ...	500 to 1,500
1. Lower Limestone Shale ...	200
Old Red Sandstone	

Near Bristol the coal measures are thinner and are divisible into three sub-groups, having a central band of hard sandstones called Pennant. This central band is traceable also in South Wales in a hard quartzose sandstone called Cockshoot rock.

The South Wales coalfield is one of the finest in Great Britain, having an aggregate thickness of 86 ft. of workable coal. In form it is an oval trough, running east and west, but divided into two portions by Carmarthen Bay. The coal measures rest upon the carboniferous limestone, the latter forming its southern, eastern and northern boundary. In the eastern portion of the field the seams are highly bituminous, in the centre the same seams are semi-bituminous, and in the west they are anthracite. This change, according to Sir H. de la Beche, occurs along a plane dipping south-east, so that at the same spot, while the coal at the base of a hill may be anthracite, those which crop out above may be bituminous.

The Bristol and Somersetshire coalfield covers an area of about 150 square miles and extends from the Mendip Hills northward about 26 miles, narrowing towards the north. A large portion of the coal measures is covered by a newer formation. On the south-west and north-east the coal measures rest upon the mountain limestone ; on the east they are covered by the Bath oolites; on the south the seams, as they approach the mountain limestone, are thrown up nearly vertical. Their peculiar contorted character resembles very much the contorted strata of Belgium and the North of France, and this, together with the great similarity in the character of the fuel, leads to the supposition that the coalfield extends from Bath to Calais.

The area of the Forest of Dean coalfield is about 34 square miles. Eight seams of coal are workable; the total thickness of the coal measures is 2,400 ft. The coal measures rest upon and are bounded on every side by the mountain limestone, and dip on all sides to the centre, forming a perfect basin. Mr. Buddle says that the principal seam of coal in this field was found interrupted by a trough or wash-fault, to which the miners gave the name of "the horse." This trough branched as the coal was worked away, apparently having been formed by a little stream with small tributaries falling into it, the course of the stream being afterwards filled up by deposited materials.

The Midland Field.—In the centre of England we have the coalfields of Leicestershire, Warwickshire, South Staffordshire, and Coalbrookdale, and other smaller fields near Shrewsbury, which differ from those both north and south of them in that they are defective at their base. They consist principally of coal measures only, resting on Cambrian or Silurian rocks, without the intervention of Old Red Sandstone or carboniferous limestone. Carboniferous limestone appears again on the northern side of the Leicestershire and Coalbrookdale coalfields, and the Old Red Sandstone, to the south of the latter, underlying the coalfield of the Forest of Wyre, letting in a thin portion of carboniferous limestone about the small coalfield of the Brown Clee Hill; but the coal measures overlap these as they die out from the north and the south respectively, and repose on the lower rocks. It would seem as though a narrow rocky island or chain of islands stretched east and west across the centre of what is now England during the early part of the Carboniferous period, so that while the carboniferous limestone was in formation in the seas to the north and south, it died out as it approached this ridge of dry land. At the still earlier period of the deposition of the Old Red Sandstone, this barrier seems to have been wider and more persistent, and to have extended through what is now Ireland, since the Old Red Sandstone dies away as we proceed from the south to the centre of both countries, and does not again appear, except as detached patches, until we reach the centre of Scotland. During the latter part of the Carboniferous period, however, the barrier was depressed, and the water in which the coal measures were deposited extended over it, so that this upper part of the formation was spread continuously across from the regions of the south to those of the north. The Leicestershire coalfield may be divided into three districts—Coleorton on the east, Moira on the west, Ashby-de-la-Zouch in the centre. This coalfield is bounded on all sides by the New Red Sandstone, but of late years coal has been found beyond what were formerly supposed to be the boundaries of the field, by sinking shafts through the New Red Sandstone. Thus a large area of the coal measures in this district may be covered by the New Red Sandstone. The central district is bounded on two sides by two down-throw faults, which bring in the coal seams of Coleorton and Moira.

The coalfield of Shropshire is triangular in shape, a very acute angle terminating near Newport; the length may be taken at about 12 miles, and the breadth about 4 miles. The western edge is defined by its outcrop where the carboniferous strata rest upon older or upon intrusive rocks; the eastern side dips under the Red Sandstone of the Permian formation, and recent explorations have satisfactorily proved that the coalfield extends beyond the line where it was formerly supposed to be lost, and there is probability that it extends as far as the South Staffordshire coalfield near Wolverhampton—the seams being identical. There are six workable seams of coal and many rich beds of ironstone.

The South Staffordshire Coalfield is one of the oldest and most remarkable in Great Britain. It is bounded on all sides by Permian and New Red Sandstone rocks, except a small portion in the northern part. It has an area of about 154 square miles, its length being about 22 miles, running north and south, and its breadth about 7 miles. Mr. Jukes says this tract of country is a gently undulating plain, having a mean height of between 400 and 500 ft. above sea level, and it may be roughly described as the space included within a boundary line drawn from Rugeley through Wolverhampton, thence to the southern end of the Bromsgrove Lickey and returning through Birmingham

Great Bar and Aldridge back to Rugeley, and appears to have been upheaved bodily along two great approximately parallel lines of fracture running from north to south. Mr. W. Blakemore, F.G.S., a gentleman who has had large practical experience in the South Staffordshire district, says that until recently it was believed that these two lines of fracture formed the accurate boundary of the coalfield, but recent discoveries by sinkings on the east side of the coal measures, at Sandwell Park and Hamstead collieries, the notable thick coal has been found to exist under the Permian, which moves the original marked boundary line two miles in an easterly direction, and still further east by the sinkings at Aldridge. He says it requires no great stretch of imagination to believe in the possibility of the continuation of these coal measures under Sutton Park, thus connecting the Warwickshire and the Staffordshire coalfields. The late Mr. Henry Johnson, an eminent mining engineer of South Staffordshire, says:—The discovery in the Aldridge district goes far to connect the Cannock Chase and South Staffordshire coalfield with the Warwickshire coalfield, and the author is strongly of opinion that were a pit put down anywhere in the neighbourhoods of Shenstone or Sutton Park a splendid field of coal would be proved, and there is every probability that there would be discovered a combination of the Cannock Chase, South Staffordshire and Warwickshire coal seams. The author's reasons for this surmise have been formed during his four years' management of the Aldridge Collieries, where the underground explorations have been in an eastward direction. Recently a down-throw fault has been worked to, which pitches the measures down at least 600ft. The line of this fault is nearly north and south so far as proved, and appears from the surface to run in a line from Barr Beacon through Lazy Hill at Aldridge to Stonnal Wood, which corresponds with the line of fracture underground. The Aldridge Colliery Company are now driving a tunnel through this fault in an easterly direction to prove the measures on the pitch side of the fault. In driving through the listing of the fault (which commenced at the Yard coal seam, the Brooch coal, the Four-Feet, the Five-Feet and the Seven-Feet Coal were passed through, all of which lay pitching on end in the listing of the fault, and as the different seams of coal were undoubtedly recognised in driving through the pitch of the fault there is every probability that they will be found at a lower level further east. As the Deep and Shallow coals at the point where we struck the down-throw fault was struck would be from 400 to 500 yards deep, and estimating the pitch of the fault to be 200 yards to the east, this would give from 600 to 700 yards deep to the Deep and Shallow coals, and it requires no great stretch of imagination to believe that they will be found overlaid by the upper measures of the South Staffordshire coalfield.

The North of England and Wales.—To the north of the Midland district the carboniferous formation is magnificently developed. In North Wales and Cumberland the base of the series rests chiefly on Upper and Lower Silurian rocks, with scraps and patches of Old Red Sandstone appearing here and there in the hollows of these rocks below the limestone. The Pennine Chain, extending from Derbyshire to the Cheviots, rises gradually from the central plains of England in a broad ridge of wild moorlands; the summits are often 2,000 ft. above the sea. This ridge is formed of a broad anticlinal curve, a good deal broken by large faults along its north-west flank towards Westmoreland and Cumberland. In Derbyshire the carboniferous limestone rises to the surface about the central portion of the anticlinal curve, and is deeply cut into by picturesque valleys, though the base of the series is nowhere exposed. As the ridge sinks towards the south the beds are overlapped and concealed by the New Red Sandstone, but on each flank of the ridge a section is shown. The coal measures mentioned in the section extend from Nottingham to Leeds on the east side of the anticlinal, while on the west side they form the coalfields of North Staffordshire, Cheshire and Lancashire. In these coalfields there is much greater thickness of coal measures, and also of millstone grit and upper limestone shale, than on the eastern side.

The North Wales coalfield extends from Flintshire to Denbighshire, and is bounded on the west by the carboniferous limestone resting upon silurian rocks, and on the north-east and south by the New Red Sandstone and the Permian formations; the general dip of the seams is north-east, and there is every probability of a large area of coal being found underneath the last-named strata.

The Cumberland coalfield stretches from Maryport on the north, along the coast of the Irish Sea to St. Bees on the south, and extends inland about five miles; here the beds crop out. From Maryport the coalfields extend eastward to Bolton. Going south of Workington the upper coals are thrown out by a large fault, which brings up the lower coal measures; going south-west the coal measures are brought in again at Whitehaven by a large down-throw fault, beyond which the coal measures dip to the east, cropping out beneath the sea, and in some instances the coal has been worked for a considerable distance under the sea. The coal measures are overlain by Permian strata from Maryport to Bolton.

The Newcastle and Durham coalfields are of an irregular basin or trough shape, extending from Staindrop on the north bank of the Tees, to the mouth of the Coquet on the south. On the north-east the coal measures extend beneath the sea, which have been worked for a considerable distance at some important collieries. On the south-east the measures continue underneath the magnesian limestone. Some of the measures contain, in small quantities, cannel coal similar to that found so abundantly in Lancashire. The measures generally dip to south under the magnesian limestone, varying in some parts to a south-east dip.

The two coalfields of Derbyshire and Yorkshire may be described as one, being connected one with the other and most of the seams bearing a striking resemblance—as, for instance, the seam known as the Top Hard, in Derbyshire, 6 ft. in thickness, gradually thickening northwards until, approaching Yorkshire, 9 ft. thick, it is known as the Barnsley thick coal. These fields extend from the town of Derby on the south to those of Bradford and Leeds on the north, and in an easterly direction they extend beneath the newer formations; they are bounded on the west and north by the millstone grit, on the south by the New Red Sandstone. The dip of the seams is generally to the east, but in the centre of the coalfield the dip is slightly reversed, the seams having a dip to the west.

The North Staffordshire Coalfield is divided by denudation into three distinct portions—(1) the coalfield of the Potteries, (2) the narrow basin of Wetley and Shafferlong, (3) the Cheadle and Ipstones coalfield. The Potteries coalfield forms a triangle, the sharp apex of which lies near Congleton and expands to the south to a width of nearly ten miles, from Longton on the east by Newcastle-under-Lyme and Apedale on the west. On the north and east the coalfield is bounded by the rise of the lower strata "hardgrit-stone," on the west by the overlying Permian beds and New Red Sandstone, and on the south by the same upper rocks in a very irregular outline, caused by the interference of faults. Along the centre portion of this coalfield the thickness of the measures is far more considerable than that of any of our English coalfields, excepting that of Lancashire. The measures are exceedingly rich, both in coal and ironstone. One most valuable feature of this coalfield is the occurrence of rich beds of carbonaceous ironstone as a roof to the seams of coal. The Wetley and Shafferlong coalfield extends from Wetley Abbey on the south to Shafferlong and Deep Hays on the north, its length being about three miles and breadth about half-a-mile. There are only two seams of coal, of little value from a commercial point of view.

The Cheadle Coalfield extends about five miles from Ipstones to Mobberley, and is about four miles from east to west. The coal measures crop out on the west, north and east, and gain in thickness as they dip under Kingsley on the south, where they are lost under the hills formed of the pebbly beds of the New Red Sandstone.

Mr. Hull gives the following as the section of North Staffordshire in the horizontal sections of the Geological Survey, sheets 42 and 55:—

	Feet.
Permian rocks	600
4. Coal measures (in three sub-divisions) ...	5,000
3. Millstone grit	4,000
2. Yoredale rocks	2,300
1. Carboniferous limestone	4,000
	15,300

The Cheshire Coalfield is bounded on the south-east by a large fault which brings the red marl nearly into contact with the mountain limestone. On the west it is bounded by a large fault known as the Red Rock fault. The coalfield is formed of the middle and lower seams of Lancashire.

The Lancashire coalfield is one of the most important coalfields in England, containing about eighteen workable seams, the two most valuable seams being the Arley mine and the Cannel coal, which thins out in all directions, having Wigan as a centre. The coal measures generally dip towards the sea. This coalfield is bounded on the north and east by millstone grit, and on the south and west by the New Red Sandstone. Faults of large magnitude traverse the whole coalfield.

The Lancashire district is stated by Mr. Hull to show the following beds:—

		Feet.
	New Red Sandstone	4,000
	Permian	500
3.	Coal measures (in three sub-divisions)	6,800
2.	Millstone grit	3,500
1.	Limestone shale	2,000

In Scotland there exist a number of distinct coalfields, separated one from another by barren tracts of the lower strata or by igneous rocks. Mr. Jukes describes these coalfields as follows:—(1.) The Lesmahagow coalfield lies to the south of the Clyde and is bounded by the Old Red Sandstone. (2.) The Clyde coalfield, broken up by intruded sheets of dolerite and melaphyre. This district is notable for the Boghead cannel, and a good quality of gas and splint coal, also for its blackband ironstone. (3.) The Midlothian coalfield consists of a double trough running north and south. The Roman Camp limestone divides the two troughs. To the north, the seams are covered by the sea of the Firth of Forth. In Fifeshire, they appear again, but greatly disturbed by introduced masses of igneous rocks. Both these coalfields produce fine seams of coal of excellent quality. (4.) The Clackmannan coalfield is divided into three districts by large faults, and divided from the Clyde coalfield by the river Forth, and from the Fife coalfield by large upthrow faults, which bring up the lower carboniferous rocks.

The coalfield of Brora, Sutherlandshire, belongs to the Oolitic period. In this coalfield there are but two seams which are workable, with some thin beds. The seams are bituminous. The main seam varies in thickness from 3 ft. 3 in. to 3 ft. 8 in. The roof of the coal consists of a compressed assemblage of leaves and stems of plants, passing into shaley coal. It is particularly characterised by a large species of equisetum. But for the evidence of the fossil shells and plants, which testify to the geological age of the strata, it might have been supposed that the coal belonged to the true coal era. The coalfield is limited in extent, it rests upon granite, and the strata belonging to the coal formation are in immediate contact with the primitive rock.

Mr. Jukes says the coal in the upper part of the coal measures of Ireland are bituminous, while those on the south are more anthracitic; the principal geological features lie between the north and south, where sandstones are developed in the lower part of the coal measures, "forming a group like the millstone grit of Derbyshire"; the separation of the carboniferous limestone by the development of a set of shales and sandstones called "the clap," in its central portion, and the entire absence of the carboniferous slate group.

THE FLORA OF THE COAL MEASURES.

The flora of the coal measures consist almost entirely of vascular cryptogams, and pre-eminently of equisetaceæ, lycopodiaceæ and ferns. The following are the commoner genera:—*Sigillaria:* A great portion of the actual coal appears to be formed of this plant, which is sometimes as much as 3 to 5 ft. in diameter, and 30 to 40 ft. in length. Its stem was fluted and marked by parallel perpendicular lines of leaf-scars, but as it grew these external markings were lost. The base of the stem passes into the roots, known as *stigmaria,* the pitted and tuberculed stems of which are such common fossils. There is little doubt, however, that stigmaria was a type of root common to more than one kind of tree. *Lepidodendron:* Trees of this beautifully-marked family attained a length of over 40 ft.; they belong to the family of club mosses, the largest existing type of which attains only a height of a few feet in tropical countries. The elegant cone *Lepidostrobus* is the fruit or catkin of the *Lepidodendron. Calamites:* These have been compared by the unlearned to bamboo, owing to their jointed and striated stem, but they belong to the equisetaceæ or horse-tail family. The foliage of the calamites consists of branches with leaves arranged in whorls or stars. The name *Asterophyllites* (*Calamocladus*) is given to jointed and fluted stems, with verticels of slim branches proceeding from the joints and bearing whorls of long, narrow, pointed leaves. In *Sphenophyllum* the leaves are fewer in number, and wedge-shaped; in *Annularia* the close-set leaves were united at the base. The ferns of the coal measures are very abundant, and in many instances resemble those of the present day. Although their forms are alike, yet identity of species, or even genus, must not be confounded, as the whole of the coal-measure ferns are extinct and their places in nature supplied with fresh races. The commoner genera are:—*Pecopteris:* The leaflets adhere by the base to the stem, and are traversed by a strong mid-rib, from which veins branch off nearly at right angles. The name *Alethopteris* is given to those species in which the pinnules are long and narrow. Ferns of this genera bear a great resemblance to the common bracken. *Neuropteris*: The leaves are heart shape and do not adhere by their bases to the stem or to one another; veins are fine, branching, and they rise from the base of the leaflet. There is no mid-rib, as in *Pecopteris*. This fern bears a resemblance to the royal fern (*osmunda regalis*). *Sphenopteris:* Leaflets contracted at their base, lobed, and the lower lobes largest. They remind the observer of the recent maiden-hair fern. *Odontopteris* is another genera which occurs less frequently than the above.

No single circumstance is so remarkable about the coal vegetation than its uniformity over a large portion of the world. From the equator to the Arctic circle the same genera, and sometimes even the same species, appear to have ranged over the whole surface of the globe.

CHAPTER II.

CHEMISTRY.

75. What is meant by the term chemistry?

Chemistry, a word of uncertain etymology, first appears in the works of the eleventh century, where it is used to designate the art of making gold artificially. It is now applied to the science which treats of the nature, laws of combination, and mutual actions of the minute particles of matter composing our globe, and the properties of the compounds they form.

76. What is meant by chemical action?

The term chemical action signifies that which occurs when two or more substances so act upon one another as to produce a third substance differing altogether from the original one, or when one substance is brought under such conditions that it forms two or more bodies differing from the original one.

77. What chemical action takes place to cause spontaneous combustion or gob fires in underground workings?

Spontaneous combustion takes place when carbonic acid gas is produced by the combination of the carbon of the small coals and the oxygen of the air; and water is formed by the combination of the hydrogen of the small coals with other portions of oxygen. Hence, ordinary combustion consists of a compound chemical action, during which carbonic acid gas and water are formed, and light and heat liberated. Light, like heat, is latent in those bodies that evolve it during chemical action; oxygen gas supplies the heat and some of the light that is given out in burning.

78. Do you consider that oxidation of iron pyrites is the chief cause of spontaneous combustion in underground workings?

No; in my experience I have never seen a gob fire of large extent in a seam containing any great amount of iron pyrites, but I have seen many gob fires in seams comparatively free from pyrites. The composition of the coal itself, when finely divided, without the aid of iron pyrites, is quite sufficient to cause spontaneous combustion in badly-ventilated seams. This has been my opinion for many years, and was stated in a paper read before the South Staffordshire Institute of Mining and Mechanical Engineers, July 1878, when Mr. Joseph Williamson, teacher of the institute chemistry class, bore out my theory by experiments before the members (*Transactions*, Vol. IV.).

79. Can you quote any other professional experience confirming this theory?

Yes; experiments were made by Fayol, who found that the absorption of oxygen by coal is effected by the temperature, and by the more or less finely-divided condition of the coal. Lignite, in a state of fine dust, inflames at 150 degs., and gas carbon at 200 degs., coke at 250 degs., and anthracite at 300 degs. and upwards. On heating a mixture of finely-powdered coal and pyrites to 200 degs. for a period of four days, the coal absorbed 6 per cent. of oxygen, while the pyrites absorbed only 3·5 per cent. From this it would appear that coal absorbs oxygen much more energetically than pyrites. This is also confirmed by another experiment, in which about 900 grammes of powdered coal and 3,350 grammes of powdered pyrites were placed in tin cans, and dried in a hot chamber. Up to 135 degs., both materials behaved similarly; but afterwards above that heat, whilst the temperature of the pyrites remained almost stationary, that of the coal rose very quickly, until, after a few hours, ignition took place. Two other samples of coal and pyrites were then put into a chamber heated to 200 degs., when the coal again quickly increased in temperature, firing in forty minutes; on the other hand, the temperature of the pyrites had in the same time only risen to 150 degs. From these experiments, it would appear the ignition of coal is not at all hastened by the admixture of pyrites, and an end is put to the old idea that only coals containing pyrites or marcasite are subject to spontaneous combustion. Fayol, who studied the question thoroughly, and conducted careful experiments as before stated, remarks in this connection:—First: The first and greatest cause of spontaneous combustion is the absorption of oxygen by the coal. Second: The most favourable conditions for the self-heating of coal are a mixture of pieces and dust, an elevated temperature, a large mass of coal, and a certain volume of air. Third: Large pieces, low temperature, small volume and the complete absence of air or good ventilation, act in opposition to self-heating. Fourth: In general, pyrites play only on unimportant—mostly insignificant—part in spontaneous combustion. Fifth: Mechanical forces, or the heat produced thereby, cannot be assigned as the usual causes of the burning of coal seams.

80. How is it that timber rots or decays sooner in a return airway than in an intake?

In return aircourses we get a larger amount of carbonic acid gas and watery vapour than in the intake; and timber, like other vegetable structures, takes up a great amount of carbon and vapour, and these two ingredients, with the timber, set up chemical action resulting in its decay.

81. What is a simple method of preserving the permanent timber structures in the vicinity of the pit bottom and also any timber at the surface, which has to be buried in the ground, such as head-frames, sills, &c.?

Timber buried in the ground, and timber structures near the pit bottom may be preserved for almost any length of time by painting them over or coating with pulverised coal and boiled linseed oil, stirring well together to the consistency of paint. Put a good coat of this over the timber. The cost will be very trifling, considering the length of time the timber will be kept from decay.

82. Would any chemical action take place if one part of the signal wire in a downcast pit were composed of iron and the other part copper, each coming in contact with the other?

No, unless some powdered sulphur and heat were applied, then chemical action would set in.

83. Under the above circumstances would chemical action take place in your upcast pit, the ventilation being produced by means of a furnace at the pit bottom?

Yes; the sulphur given off from the furnace coming in contact with the copper signal wire would set up chemical action, and eventually the copper wire would disappear.

84. What material would you recommend for the signal wire in your two shafts, viz., the upcast and downcast respectively, and why?

I would recommend a copper signal wire for the downcast, as water would not have the same chemical effect upon it as upon iron, and I would recommend an iron wire for the upcast, as the sulphur from the furnace would not have the same chemical effect upon it as upon the copper one where the shaft is dry.

85. In a wet furnace shaft would there be rapid corrosion of the wire of the winding rope or other iron exposed to the heat and wet?

Yes; there would be rapid corrosion of any iron in a wet furnace shaft, caused by the action of hydrated sulphuric acid, produced by the sulphur in the coals, which, after being driven off in the form of vapour by the heat of the furnace, combines with oxygen from the air, forming sulphurous anhydride (SO_2); this, when brought into contact with water or moisture in the air, is absorbed, and combining with part of the oxygen of the water, forms hydrated sulphuric acid. This solution running down the surface of iron in the shaft, is not evaporated, its boiling point being much higher than that of water, and it hence becomes more highly corrosive as it descends. Iron wire placed in a furnace shaft for one month has been known to lose one-third of its strength. A similar result is seen in the case of metal tubbing, which, after being in a furnace shaft for a few years, was reduced to one-third of its previous weight, and contained only 60 per cent. of iron. Continuous heat, in a dry furnace-shaft, is not considered injurious to iron constantly exposed to its influence, but it is doubtful whether the same could be said of a wire rope, subjected to varying temperatures and to the expansion and contraction involved in passing from, say, 300 degs. to 40 degs.

86. What is the atmosphere?

The atmosphere is the gaseous envelope encircling the earth, and it constitutes the ocean of air, at the bottom of which we live.

87. Give the composition of the atmosphere.

The atmosphere consists almost entirely of a mixture of two gases, oxygen and nitrogen, with a trace of carbonic acid. In addition to these the air contains aqueous vapour and ammonia gas.

88. Give the composition of the atmosphere by weight and volume.

One cubic foot of air weighs, at a temperature of 32 degs. Fahr., and under a pressure of 15 lb. per square inch, 0·085 lb., so that under the same conditions 1,000 cubic feet weigh 85 lb. Dry air is chemically composed of 77 per cent. of nitrogen and 23 per cent. of oxygen by weight, or 79 per cent. of nitrogen, and 21 per cent. of oxygen by volume. One cubic foot of nitrogen weighs 0·08 lb., so that under the same conditions 1,000 cubic feet weigh 80 lb. One cubic foot of oxygen weighs 0·09 lb., so that under the same conditions 1,000 cubic feet weigh 90 lb., so that a mixture of 770 lb. of nitrogen and 230 lb. of oxygen makes 1,000 lb. of common dry air. As the oxygen is heavier, it occupies less bulk in proportion, so that if we take the air by volume, 790 cubic feet of nitrogen and 210 of oxygen make 1,000 cubic feet of air, which will weigh 85 lb. The amount of watery vapour is very variable, it changes from hour to hour, and differs in different localities.

89. In what proportion is carbonic acid gas present in the atmosphere, by volume?

Carbonic acid is less variable than water vapour, and changes only from $\frac{1}{2500}$th part to about double that amount. Notwithstanding, carbonic acid (with water) is the important element in the vegetable kingdom, and plants could not live in an atmosphere composed only of oxygen diluted with nitrogen.

90. By what experiment can the quantity of carbonic acid gas present in the atmosphere be ascertained?

The quantity of carbonic acid gas contained in the air can be found by drawing a known volume of perfectly dry air through weighed tubes containing caustic potash; the increase in weight of these tubes gives the weight of carbonic acid contained in the air drawn through.

91. Give the symbol, combining weight and density of hydrogen.

The symbol of hydrogen is H, combining weight 1, and density 1.

92. Give the symbol, combining weight and density of nitrogen.

The symbol of nitrogen is N, combining weight 14, density 14.

93. What is the symbol, combining weight and density of oxygen gas?

The symbol of oxygen is O, combining weight 16, and density 16.

94. Also give the symbol, combining weight and density of carbon.

The symbol for carbon is C, combining weight 12, and density 12.

95. Give the symbol, combining weight and density of carbonic acid gas, and how you ascertain the density;

The symbol for carbonic acid gas is CO_2, combining weight 44, density 22. The density may be ascertained thus :— $CO_2 = \frac{12 + 32}{2} = 22 =$ density—that is, carbonic acid gas is twenty-two times heavier than an equal volume of hydrogen.

96. Give the symbol, combining weight and density of light carburetted hydrogen or marsh gas.

The symbol for light carburetted hydrogen gas is CH_4, combining weight 16, density 8. This gas is eight times the weight or density of an equal volume of hydrogen gas, and is found in coalmines, known by the name of firedamp.

97. Give the symbol, combining weight and density of carbonic oxide gas.

The symbol for carbonic oxide gas is CO, combining weight 28, density 14. This gas is produced by coal fires, the oxygen of the air, which enters at the bottom of the grate, combining with the carbon of the coal to form carbonic oxide. It is also produced by the explosion of gunpowder and is called whitedamp when met with in coalmines.

98. What is understood by the terms symbol, combining weight, and density of gases?

In order to express the composition of substances more conveniently than can be done by writing the names of the elementary constituents at full length, chemists use a kind of shorthand or symbolic language. The first letter or the first two letters of the name are alone employed to distinguish the elements. The symbols, however, signify more than this; they stand not only for the elements in question, but they all have certain numbers belonging to them which indicate the proportions by weight in which the several elements are found to combine with each other; thus CO_2 signifies carbonic acid gas, the combining weight being $\frac{44}{2} = 22$ density. The density or weight of a given volume of oxygen compared with that of the same volume of hydrogen is found to be 16—hydrogen, as the lightest body known, being taken as the unit.

99. Can you give the weight of one litre of hydrogen gas?

The weight of one litre of hydrogen gas at the standard pressure and temperature weighs 0·08936 grammes. Thus, under the same circumstances,

				Grammes.
1	litre of	oxygen	weighs	$16 \times 0{\cdot}08936 = 1{\cdot}430$
1	„	nitrogen	„	$14 \times 0{\cdot}08936 = 1{\cdot}251$
1	„	chlorine	„	$35{\cdot}5 \times 0{\cdot}08936 = 3{\cdot}172$
1	„	sulphur vapour		$32 \times 0{\cdot}08936 = 2{\cdot}860$

In the same manner the weight of any gas may be found by the above method.

100. Can you give the several units of measurement?

The metrical unit for length is the metre, the ten-millionth part of the distance from the earth's equator to the pole. The unit of capacity is the litre; it is the cube of a decimeter side. The unit of weight is the gramme, the weight of a cubic centimetre of distilled water at 40 degs. Fahr. The unit of force is the kilogrammetre, being the force required to raise one kilogramme weight one metre high. The unit of electric resistance is the ohm; it is the resistance which a current undergoes when passing through a column of mercury one metre long and one square millimetre in section at the freezing point of water. The unit of electro-motive force is the volt; it is the amount of electro-motive force produced by one Daniell cell. The unit of electrical intensity is the ampère; it is the current produced by one volt through a resistance of one ohm.

The unity of quantity of current is the coulomb; it is the quantity of electricity given by one ampère in one second.

101. What is the chemical composition of water?

Water consists of 2 parts by weight of hydrogen and 16 parts by weight of oxygen, and its chemical symbol is therefore H_2O, which not only indicates that it is composed of 2 parts by weight of hydrogen and 16 of oxygen, but also that 2 volumes of hydrogen have united with 1 volume of oxygen to form 2 volumes or 1 molecule of water gas.

102. What are the equivalents of the litre and gramme in English denominations?

The litre is rather less than an English quart. The weight of a gramme is 15·432349 grains, or nearly 15½ grains English weight.

103. Can you give the weight of a cubic foot of some of the gases?

Yes; the following is a short table of the specific gravity, the weight of a cubic foot, and the symbols of some of the principal gases.

	Specific gravity.	Weight of a cubic foot.	Symbols.
Air	·001293	·08072	ON_3
Carbonic acid	·00197	·123	CO_2
Hydrogen	·0000895	·0056	H
Nitrogen	·00125	·078	N
Oxygen	·00143	·089	O
Steam	·0088	·055	H_2O

104. How is the specific gravity of mercury or any other body ascertained?

The specific gravity of a body is the proportion which exists between its weight and that of an equal bulk of distilled water at a temperature of 60 degs. The reason for fixing upon a certain temperature is that as water expands when heated, a cubic inch of hot water weighs less than an equal bulk of cold. The temperature of 60 degs. is chosen merely as a matter of convenience—that being about the average temperature of water. When we say that the specific gravity of mercury is 13·6, we mean that a certain amount of mercury weighs 13·6 times as much as an equal bulk of distilled water at 60 degs. The weight of a cubic inch of distilled water is 252·5 grains; a cubic inch of mercury, therefore, weighs 252·5 grains × 13·6 = 3,434 grains, which is nearly 8 oz.

105. Can you give a table of the specific gravity and combining weight of gases?

Yes; the following is a table, for which I am indebted to Mr. William Farmer, of New York. It contains some of the elements and compounds, with their combining weights, volumes and specific gravities. He says:—"When the combining weight of any of these elements and compounds is taken in pounds, then the gas or vapour therefrom will always occupy about 377·07 cubic feet of space, at 60 degs. Fahr. and 30 in. barometer. If we divide this constant 377·07 by the combining weight of any of the substances, then the quotient will be the number of cubic feet per pound of the same. If we divide the combining weight of any of the substances given in the table by 2 then the quotient will give the density of the same, as compared with hydrogen. If we divide the combining weight of any of the substances by the constant 28·87, then the quotient will be the specific gravity of the gas or vapour therefrom, as compared with air. All the calculations are based on the atomic weights which are now generally adopted by chemists."

	Combining weight.	Cubic feet. per lb.	Cubic feet per combining weight.	Specific gravity. Air = 1.
Hydrogen (H_2)	2·00	188·53	377·07	0·0692
Carbon vapour (C_2)	24·94	15·75	377·07	0·8292
Nitrogen (N_2)	28·06	13·43	377·07	0·9719
Oxygen (O_2)	31·92	11·81	377·07	1·1056
Chlorine (Cl_2)	71·00	5·31	377·07	2·4593
Bromine (Br_2)	160·00	2·35	377·07	5·5420
Fluorine (F_2)	38·00	9·92	377·07	1·3162
Iodine (I_2)	253·20	1·48	377·07	8·7703
Sulphur (S_2)	63·96	5·89	377·07	2·2154
Phosphorus (P_4)	123·84	3·04	377·07	4·2895
Carbonic oxide (CO)	27·93	13·50	377·07	0·9674
Carbonic acid (CO_2)	43·89	8·59	377·07	1·5202
Water vapour (H_2O)	17·96	20·99	377·07	0·6221
Hydrogen sulphide (H_2S)	33·98	11·09	377·07	1·1770
Ammonia (H_3N)	17·03	22·14	377·07	0·5898
Sulphurous oxide (SO_2)	63·90	5·90	377·07	2·2133
Sulphuric oxide (SO_3)	79·86	4·72	377·07	2·7662
Cyanogen (C_2N_2)	52·00	7·25	377·07	1·8011
Bisulphide of carbon (CS_2)	75·93	4·96	377·07	2·6300
Ethyl alcohol (C_2H_6O)	45·90	8·21	377·07	1·5898
Ethyl ether ($C_4H_{10}O$)	73·82	5·10	377·07	2·5576
Methyl alcohol (CH_4O)	31·93	11·81	377·07	1·1059
Methyl chloride (CH_3Cl)	50·47	7·47	377·07	1·7482
Carbonyl chloride ($COCl_2$)	98·93	3·81	377·07	3·4267
Phosphine gas (PH_3)	33·96	11·10	377·07	1·1763
Hydrochloric acid (HCl)	36·50	10·33	377·07	1·2642
Methane (CH_4)	15·98	26·61	377·07	0·5531
Ethane (C_2H_6)	29·94	12·59	377·07	1·0370
Propane (C_3H_8)	43·91	8·58	377·07	1·5209
Butane (C_4H_{10})	57·88	6·51	377·07	2·0048
Ethene (C_2H_4)	27·94	13·49	377·07	0·9677
Propene (C_3H_6)	41·91	8·99	377·07	1·4516
Butene (C_4H_8)	55·88	6·74	377·07	1·9355
Ethine (C_2H_2)	25·94	14·53	377·07	0·8985
Propine (C_3H_4)	39·91	9·44	377·07	1·3824
Butine (C_4H_6)	53·88	6·39	377·07	1·8662
Quintine (C_5H_6)	65·85	5·72	377·07	2·2809
Benzene (C_6H_6)	77·82	4·84	377·07	2·6955
Styrolene (C_8H_8)	103·75	3·63	377·07	3·5936
Naphthalene ($C_{10}H_8$)	127·70	2·95	377·07	4·4232
Turpentine ($C_{10}H_{16}$)	135·70	2·77	377·07	4·7003
Dry air	28·87	13·06	377·07	1·0000

106. How many parts of air with one part of firedamp will make an explosive mixture?

When firedamp forms 1 part out of 13 of air the mixture becomes explosive, so that if ignited by an exposed flame the whole of the mixture will be converted into a mass of flame; in the proportion, however, of 1 of gas to 5 parts of air the mixture will not explode, but, on the contrary, will extinguish the flame of any candle or lamp that may be brought into it.

107. Give the proportion of air to one part of firedamp at which the explosive force will be at its greatest point.

The explosive force would be at its greatest point when 1 part of firedamp is mixed with 9 parts of air; or, say, if ignited it would explode with its greatest energy or force at this proportion; but as the proportion of firedamp becomes greater than 1 part to 9 of air, by volume, so the force of the explosion becomes less.

108. What is meant by the diffusion of gases?

Gases which, when mixed together, do not combine chemically, but have the power of becoming intimately mixed together; this is called the diffusive power of gases.

109. Can you give any rates or proportion of the diffusion of gases with air?

The rate of the diffusion of gases with air entirely depends upon the specific gravity or density of the gas; thus, a bottle filled with hydrogen lost 94·5 per cent. of this gas when left exposed to the air in the same time that a bottle of carbonic acid gas lost only 47 per cent.; or we may say if there are two galleries in the underground workings of a mine, one of which contains 94·5 cubic feet of hydrogen gas and the other 47 cubic feet of carbonic acid gas, and an equal volume of air passes through each gallery, the one containing the hydrogen will become clear or the gas be diffused exactly in the same time as the one containing the carbonic acid, all other things remaining the same. Experiments made upon this subject have shown that the velocity of diffusion of the different gases is inversely proportional to the square roots of their densities. The velocity in this case means the rate of diffusion, or, in other words, 4 volumes of hydrogen can be diffused in the same time as 1 volume of oxygen can, all other things remaining the same, oxygen being 16 times heavier than hydrogen.

[The gases which constitute the atmosphere do not arrange themselves in layers according to their specific gravities. If it were so we should have the poisonous gas carbonic acid resting upon the earth, its specific gravity being 1·527 (air being 1·000); oxygen would form the second stratum, its specific gravity being 1·105; nitrogen would form the upper stratum, far beyond the reach of animal life, its specific gravity being 0·972.]

110. When a volume of carbonic acid gas is suddenly liberated from a cavity or from abandoned workings, will it—being a heavy gas—roll down to the lowest parts of the workings in the vicinity, and, on the same principle, will hydrogen gas similarly liberated ascend through the air and spread itself in a layer next the roof, hydrogen being a light gas?

Yes; the heavy gas will descend to the lowest point, and the light gas will ascend to the highest point in the mine, but neither will remain separate, for, by the law of diffusion, even while passing through the air of the mine they will assimilate with it in such a way that, where the quantities are not too great, the gases will be diluted and rendered harmless.

111. What is meant by whitedamp, and what effect has it upon persons in underground workings where it is present?

Whitedamp is a mixture of gas and air in which candles and lamps will burn, while life will become extinct. Many deaths have occurred in the mines through the presence of this gas, although the lights have burned brilliantly. It will cause giddiness, sickness and debility if breathed, even when mixed with a fourth of its bulk of air. Its ingredients consist of oxygen and carbon; out of 100 parts by weight there are 56·69 of oxygen and 43·31 of carbon. Its specific gravity is 975·195, that of air being 1,000; it is therefore a little lighter than air. Air containing 1 to 2 per cent. is totally unfit to sustain life. Carbonic oxide is a narcotic poison, and like carbonic anhydride (which it produces when burned), enters the blood through the lungs. Its presence in the blood can be detected after death.

112. Under what circumstances is carbonic oxide gas, called whitedamp, met with in underground workings?

Carbonic oxide gas is met with when the underground workings are insufficiently ventilated, and when gunpowder is allowed to be used or exploded to a great extent in them; this gas also is produced by the combustion of coal or wood, and it is stated that the deaths of the men and boys at the great Hartley Colliery accident were attributable to this gas, it being given off from the furnace through the stoppage of the air current, consequent on the closing in of the shaft.

113. Under what circumstances is sulphuretted hydrogen gas met with in coalmines?

Sulphuretted hydrogen gas is found in old unventilated workings partly filled with water; or in old workings, owing to the action of the water upon pyrites. When this gas is present in the air of the underground workings, the candles or lamps will burn in the mixture, but if not detected by its odour it may prove fatal to life before its presence can be otherwise detected. Its ingredients are sulphur and hydrogen. Out of 100 parts by weight there are 94·15 of sulphur and 5·85 of hydrogen, its specific gravity being 1,174·88, that of air being 1,000.

114. Has sulphuretted hydrogen gas any injurious effect on the eyesight?

Yes; if miners are allowed to work for any length of time in an atmosphere containing only a small percentage of sulphuretted hydrogen gas their eyesight will be affected.

It will cause dimness of sight, shortsightedness, giddiness and twitching of the eyes when looking up or downwards.

115. How would you purify water for drinking purposes when it is hard or discoloured?

First I would boil it and then filter or distil it; and to satisfy myself whether the matter which the water held in solution was mineral, vegetable, or animal, I would test it by mixing a few drops of baric chloride, or argentic nitrate or ammonia, or ammonic oxalate with a glass of the water for each separate test; the impurity would then appear as a cloudy or muddy precipitate in the vessel.

116. Under what circumstances is carbonic acid gas, called blackdamp, met with in underground workings?

Carbonic acid gas (CO_2) is produced in the underground workings by the decay of organic matter, by the breath of men and animals, and by the combustion of all substances containing carbon; it is given off in abundance in shallow mines, especially in the 10-yard thick coal of South Staffordshire. It appears to be held imprisoned in large quantities in the strata, since it often accumulates in mines where none of the above-named causes will account for the large volumes sometimes met with.

117. At what temperatures do explosive mixtures of gas ignite?

The temperatures at which various mixtures of gas and air ignite have been carefully investigated by two French chemists, MM. Mallard and Le Chatelier, their experiments having been carried out with hydrogen as well as carbon gas, mixed with air in different proportions. The temperature was recorded by a pyrometer heated in a Plorot melting furnace, and the interior of the pyrometer was connected with a gas reservoir and with the air in such a manner that the mixture to be tested could be admitted immediately the desired temperature was reached. In order to prevent mistakes, repeated experiments were made at degrees of heat which were purposely fixed a little under or over the point of ignition as already ascertained. From the results of these tests it was found that a mixture of 70 parts of air and 30 parts of hydrogen gas ignited at a temperature of from 1,026 degs. to 1,028 degs. Fahr., while the temperature of ignition for a mixture of air and carbon gas in similar proportions varied from 1,202 degs. to 1,215 degs. Increasing the proportion of carbon gas, it was found that the point of ignition could be further raised to 1,337 degs.

118. Give the mixture of air before an explosion of firedamp and the mixture after an explosion.

MIXTURE BEFORE EXPLOSION.

		Number of atoms.		Relative volume per atom.		Uncombined volume.	Per cent.
Air ...	Oxygen	4	×	1	=	4	90·4
	Nitrogen... ...	7·4	×	2	=	14·8	
Firedamp	Carbon	1	×	2	=	2	9·6
	Hydrogen ...	2	×	2	=	4	
						24·8	100·0

MIXTURE AFTER EXPLOSION.

		Number of atoms.		Relative volume per atom.		Uncombined volume.	Per cent.
	Free Nitrogen ...	7·4	×	2	=	14·8	71·2
Carbonic acid gas	Carbon	1	×	2	=	2	9·6
	Oxygen	2	×	1	=	2	
Steam ...	Hydrogen ...	2	×	2	=	4	19·2
	Oxygen	2	×	1	=	2	
						24·8	100·0

There may happen to be present before an explosion either an excess of air or of firedamp beyond what is necessary to cause the explosion. The afterdamp, as will be seen by the second table, contains a large proportion of nitrogen, and it is this which makes it so injurious and fatal to those in the mine, and to explorers, as it acts very powerfully on the human system, rendering its victim unconscious, the sensation produced being that of falling asleep.

119. Suppose an underground gallery contained an accumulation—say, 1,000 cubic feet of firedamp—at its highest explosive point? What would be the power or force of the explosion should the gas be ignited?

This cannot be accurately determined, but it has been found by experiments that one pound of firedamp when ignited will produce 24,244 heat units, and as every heat unit is equal to 772 foot-pounds, we may form an approximate idea of the actual force produced by a given volume of firedamp when ignited. For example, we will suppose 1,000 cubic feet of firedamp to weigh 45 pounds :—

Then $\frac{45 \times 24{,}244 \times 772}{33{,}000} =$ 25,522-horse power force produced.

120. An underground gallery of uniform section contains an accumulation of firedamp, filling it 10 ft. backwards and across its whole face. If ignited, what distance back will the flame extend, supposing it to extend no further than the distance due to expansion?

This cannot be accurately determined, the expansion depending on a variety of causes—viz., the percentage of gas present, the temperature of the mine, the amount of fresh air available to supply oxygen, &c. But it has been found by experiment that the flame of a violently explosive mixture will expand to about eight times the volume of the gas. Under the conditions stated in the question, therefore, the flame would reach 10 ft. × 8 ft. = 80 ft. backwards.

121. Would a mixture of firedamp and air—say, just below the explosive point—become explosive if suddenly compressed, as by the discharge of a heavy blown-out shot, a sudden extensive fall of roof, or an explosion in the adjoining workings?

I believe that experiments have proved this would be so, the probable cause being the elevation of temperature by compression, and the closer proximity of the molecules favouring the ignition of the oxygen.

122. During a sudden and extensive fall of roof in the gob or goaf, are sparks ever produced by the falling rocks? If so, do you consider such sparks sufficient to ignite firedamp present at an explosive point?

Yes; I am of very strong opinion that an explosion may occur when the rock in the gob or goaf is falling or breaking down, and where firedamp is present, especially should the rock contain ironstone or iron pyrites. I have seen both sparks and flames under these conditions. I have also frequently observed both sparks and flame fly from miners' picks, &c., when breaking or chipping stone or rock in the goaf, and it has long been my opinion that these sparks are sufficient to ignite gas. To bear out my theory, I give some particulars of an explosion at the Milton Gasworks, Burslem, by which a workman was killed. On the day of the explosion the deceased was employed in taking out a washer from a pipe connected with the gas-main at the works, in order to replace it with a new one. Whilst chipping out the lead which had been run into the joint, with a cross-cut chisel and hammer, the chisel "broke" in the lead about an inch from the point. A second blow drove the shaft of the chisel against the broken point, and caused the emission of a spark which exploded a large quantity of gas in the pipe. It was proved beyond doubt that the spark from the chisel was the cause of the explosion.

123. In what way does compression raise the temperature of an explosive mixture?

When an explosive mixture is compressed the latent heat is condensed in the same ratio as the volume is reduced, and the heat is consequently concentrated, just as latent heat is developed when air is compressed by the air-compressor.

124. Is the volume of flame from a given quantity of firedamp always the same?

No; the volume of flame which a body of firedamp will produce depends on the quality of the mixture. The air in the workings may become charged with gas just below the explosive point, only a few yards next the face being explosive; but when ignited the pressure would run back, and render some of the mixture which before was below the explosive point, explosive.

125. If gas only produces eight times its volume of flame, how is it that in an explosion the flame sometimes reaches up the shaft to the surface?

When gas is ignited in an underground gallery, especially in straight places, the flame generally flies back a considerable distance. Accumulations of gas are often pure gas next the face and diluted as they reach back, tailing off to a thin stratum against the top. At the utmost point the gas may be just explosive, while at the face several feet may be purely pure gas. When such a body of gas is ignited its force cannot expand inwards, and therefore the whole mass expands outwards. The flame rushes back with the force of the explosion, and the gas with it, until meeting with fresh air all the gas is consumed, but when the flame is at the furthest point back, there may be flame at the face. The sudden expansion arising from the excessive heat produces a vacuum, so that when the force of the explosion is spent, a reaction sets in and the rush is towards the face again. I have known cases where a body of gas has been exploded and yet the person who ignited it has escaped with a few burns. By comparing the volume of gas with the point the flame has reached, I think it will be found that the volume of flame never exceeds eight times that of gas. When the flame is carried a long distance from the point of first ignition, it is travelling back against the fresh air to obtain oxygen, or the air may be surcharged and only requires the heat and compression to make it explosive and so carry the flame onwards. Coaldust is another factor, and even though not itself causing the explosion, it rises in clouds, and feeding the flames, aggravates and prolongs the explosion. Cases have happened where the flame has reached up the shaft to the surface, the explosion starting a mile from the shaft, yet some of the men on the route have escaped. Now if the whole distance had been filled with flame, the heat alone would have rendered escape impossible, not to speak of the afterdamp. The volume of flame and the expansive force of an explosion are two very different things; the flame of the powder and force of the blast must not be confounded.

126. Recapitulate the gases which are met with in mines, and which are injurious to the health of persons breathing them.

Afterdamp, the result of an explosion of a mixture of air and firedamp; carbonic acid gas, called blackdamp; carbonic oxide gas, called whitedamp; sulphuretted hydrogen gas, sometimes called stonedamp; light carburetted hydrogen gas, called firedamp.

127. What is the best means of restoring a person suffering from the effects of afterdamp or asphyxia?

Miners are liable to asphyxia when entering abandoned unventilated workings, and especially after an explosion has occurred—in other words, when exposed to an atmosphere deprived of its oxygen. The following are remedies which should be applied as soon as possible to persons suffering from the effects of afterdamp:—

(1.) Persons affected should be immediately withdrawn from the deleterious place, and exposed to a pure atmosphere.

(2.) Undress them and bathe their bodies in cold water.

(3.) Make them swallow, if it be possible, cold water adulterated with vinegar.

(4.) Clysters should be given, two-thirds of cold water and one of vinegar, to be followed with others of a stronger solution of common salt or of senna and epsom salts.

(5.) The nose should be irritated with the feather end of a quill, which should be gently moved in the nostrils of the insensible person.

(6.) Air should be introduced by blowing into the lungs with the nozzle of a bellows into one of the nostrils, and compressing the other with the fingers.

(7.) If the above means do not produce the desired effect, the body of the asphyxiated remaining warm, which is generally the case for a long time, it may be necessary to bleed, which is indicated by the redness of the face, swollen lips and protruding eyes. Blood-letting from the jugular vein will be the most effective; in default of drawing it from that place; it should be taken from the foot.

(8.) The above remedies should be promptly applied; the longer they are delayed the less efficacious are they likely to be, but as death does not ensue for a long time, the remedies ought to be continued until it is certain. The absence of the pulsation of the heart is not a sure sign of death, neither is the want of respiration. Neither ought they to be regarded as dead whose breath does not dim the surface of glass, nor whose limbs are stiff and who appear insensible.

128. What are the symptoms of asphyxia ?

The symptoms of asphyxia or suffocation from after-damp may be easily recognised; they are somewhat as follows:—The features are distorted, the face is often livid, the countenance swollen and marked with reddish spots, the eyes protrude and there is sudden cessation of the pulsation of the heart and of the action of the senses.

129. Is the poisonous effect of carbonic acid gas felt for any length of time after the patient has been partially restored by medical treatment ?

Yes; in the following instance in which carbonic acid gas was inhaled, death resulted after the expiration of seventeen days, The case is that of Thomas Banel, of Aspull, near Wigan, who inhaled carbonic acid gas while working in the Kirkless Hall Colliery. Mr. Luther Cooke, surgeon, gave evidence before the coroner's jury showing that death was the result of congestion of the brain following poisoning by carbonic acid gas. He had no doubt whatever that deceased died from having inhaled carbonic acid gas. I quote this instance only to show the great importance of prompt medical attendance in cases of asphyxia, even after restoration has been effected by any of the means given above.

130. Name the colour, taste, and odour of some of the principal gases met with in mining.

Oxygen has no colour, odour, or taste. Hydrogen is a tasteless, colourless, odourless gas. Nitrogen has no taste, colour, or odour. Carbon is a solid element and is not known in the free state either as a liquid or a gas. Carbon is remarkable as existing in three distinct forms. These three allotropic forms of carbon are—(1) diamond, (2) graphite or plumbago, (3) charcoal; these substances differ in hardness, colour, specific gravity, &c. In addition to the carbon which is found free in these three forms, and that contained, combined with hydrogen and oxygen, in the bodies of plants and animals, it exists combined with oxygen as free carbon dioxide in the air, and with calcium and oxygen as calcium carbonate in limestone, chalk, marble, corals, shells, &c.

131. If you wish to extinguish an underground fire with carbonic acid gas, how would you prepare the gas for use?

This gas can easily be prepared by the decomposition of limestone with hydrochloric acid.

[Pupils who are desirous of gaining a knowledge of chemistry will find the little work on *Elementary Chemistry*, by H. E. Roscoe, a good help to them.]

132. Give the composition of gunpowder.

The composition of English war powder is as follows:—

	Pounds.
Saltpetre	75
Sulphur	10
Charcoal	15
	100

133. Give the composition of glycerine.

Glycerine ($C_6H_8O_6$), also known as hydrated oxide lipyl or hydrated oxide of glyceryl, was discovered in 1779 by Scheele, who obtained it in the preparation of lead plaster, and named it "the sweet principle of oils." It is a colourless, viscid, neutral, uncrystallisable, inodorous fluid.

134. What is the composition of nitro-glycerine?

Nitro-glycerine, otherwise known as glonoin or glonoin oil ($C_6H_5N_3O_{18}$) or [C_6H_5 (NO_4) O_6] is a compound produced by the action of a mixture of strong nitric and sulphuric acids on glycerine at low temperatures. It is a light yellow, oily fluid, with a specific gravity of 1·6. It is inodorous, but has a sweet, pungent, aromatic taste.

135. What is the composition of guncotton?

Guncotton was discovered by Schoubein in 1845 (within two years of the discovery of nitro-glycerine), and is made from cotton-waste immersed in one part of nitric acid and three parts of sulphuric acid. It is insoluble in water, is little affected by heat until 300 degs. Fahr. is reached, when it explodes if confined; but if fired in the open air it burns with a large flame. One of its chief advantages is that it explodes without producing smoke, and, therefore, allows miners to return to their work much sooner than when powder is used. It is handled without much risk of accident, and is not affected by the damp or cold.

136. Give the relative power of some of the principal explosives, compared bulk for bulk.

Interesting as it may be to compare the relative power of explosive substances, weight for weight, the power which they are capable of exercising, bulk for bulk, is of far greater importance in its application to blasting. It is easily computed when the specific gravity is known, which has been found for nitro-glycerine, 1·6; for guncotton, 1·00; for dynamite, No. 1, 1·65; for ammonia powder, 1·55; for gunpowder, 1·00; and for lithofracteur, 1·70, which is also the specific weight of dynamite No. 2, and also of most of the nitro-glycerine preparations containing large quantities of metallic salts. When their power is compared bulk for bulk the various explosives range as follows:—

Nitro-glycerine	100
Ammonia powder	80
Dynamite No. 1...	74
Lithofracteur	53
Guncotton	45
Curtis and Harvey's blasting powder fired by detonation	17·5

[The following is a description of the explosive "Roburite." It is the invention of Dr. Carl Roth, and consists of a mixture of two substances, neither of which separately possesses explosive properties; both components are solid, and the resulting mixture has a sandy granular appearance, somewhat resembling the commonest yellow sugar. Neither friction, percussion, nor heat will cause it to explode, and it does not freeze. Damp, however, causes it to loose power, but this can be restored by drying. Roburite can only be exploded effectively by a specially strong detonator, containing one gramme of pure fulminate of mercury. It is practically flameless and does not pulverise the coal. The amount of noxious gases produced by its explosion are infinitesimal. The report from a mine in Westphalia, with shafts about 1,500 ft. deep, states, "the men are not inconvenienced by the gases and experience no difficulty whatever in breathing the moment after a shot has been fired, and they resume their labour at once." In tamping, care must be taken to ram lightly for the first six inches; afterwards tamp firmly for about 2½ ft. When detonated, roburite produces neither spark nor flame, and will not, therefore, ignite firedamp nor coaldust in mines. Dr. Roth states that this point was decided by the trials of the Imperial German Commission on Accidents in Mines, and that, in consequence, this explosive is now being introduced into the coalmining regions of Germany as affording absolute safety to the men employed.]

137. What is the composition of coal?

Coal is chiefly composed of carbon—viz., 74 to 97 per cent. The specific gravity—or, in other words, the weight as compared with water—varies between 1·3 and 1·5. The weight of a cubic foot of solid coal equals 72 to 84 lb. It occupies from 40 to 50 cubic feet per ton when broken. It is found in the formations of the palæozoic age, and it also occurs in secondary and tertiary strata.

CHAPTER III.

BORING, SINKING, TUBBING, WALLING, &c.

138. How would you first proceed in searching for coal?

First, by taking a general survey of the district, observing the nature of the ground through which the rivers and brooks have scooped their way, and examining quarries or the section shown by any raised cliffs in the neighbourhood.

This subject is of the greatest importance to students, who are apt to depend entirely on their own theoretical knowledge when answering questions upon it. I would advise those especially who have not had the privilege of being stationed where sinking operations have been carried on, to make themselves generally familiar with the rocks and minerals of any district in which they may find themselves, and whenever out on an exploration, to have with them a good geological map of the district.

139. When coal is known to be under an estate, and it is decided to sink, what are the first considerations?

In the first place, choice has to be made of a spot where the sinking shall be. To determine this, many points have to be taken into consideration—the rise and dip of the strata, the position of any large faults, and the situation of the colliery in regard to markets and transit facilities.

140. If it is not certain whether there is coal, &c., under an estate or not, by what means can the fact be ascertained?

Either a borehole or holes may be put down, or the sinking of a trial shaft be undertaken.

141. Explain in short the ordinary method of boring.

First, the headgear is erected over the borehole for the purpose of lifting and lowering the rods when they require lengthening or the cutting-chisel requires to be changed. The headgear is usually erected at a good height, so that by means of a crab or windlass the rods may be lifted in as long lengths as possible, reducing to a minimum the number of times the rods will need screwing and unscrewing, which, in a deep hole, is rather important. The rods vary in length from one or two feet up to eighteen, made of iron about one inch in diameter. A sheave or a pair of blocks are hung from the top of the headgear, and a rope run through them, one end being attached to the crab or windlass, the other hanging loose over the borehole. The rods are raised to give the blow, sometimes by hand, sometimes by the windlass, but most generally by a spring pole, and a rotary motion is given to them by the man in charge at the top of the hole by means of a cross-bar. After the chisel or cutter has penetrated the rock, the loose *débris* is brought up by a tool called a "sludger," and by examining the *débris* brought up the nature of the ground passed through can be ascertained.

142. Of what service is the sinking of a small staple or pit before commencing boring?

The length of the lift or off-take, as it is termed, depends altogether upon the height of the pulley at the top of the borehole; if, where the clay or gravel is dry, a small staple is sunk to the depth of a few fathoms, from the bottom of which the borehole is commenced, a great deal of time will be saved, as the rods can be taken off at longer lengths. There are also other reasons for sinking a staple, for suppose the depth from the surface to be 100 fathoms, the sinking of the staple 5 fathoms will diminish the cost of boring by the cost of the lowest 5 fathoms, which will amount to £37 10s. The risk of accidents, which becomes greater as the depth of the hole increases, is also diminished proportionately.

143. Can you give any particulars as to the cost of boring?

Boring is generally contracted for, labour and material being found according to a regulated scale of charges, which is given as follows:—

	£	s.	d.	
For the first five fathoms	0	7	6	per fathom.
„ second „	0	15	0	„
„ third „	1	2	6	„

and so on in arithmetical progression, advancing 7s. 6d. per fathom for every additional five fathoms in depth. The following is the rule given for finding the cost of a borehole at the above prices, the depth of the borehole being given, say 60 fathoms:—Consider the question as a series in arithmetical progression whose first term is (5 × 7·5s.) = 37·5s., and the last term 37·5s., multiplied by the number of fathoms divided by 5—

$$\text{Here } \frac{60}{5} = 12, \text{ the number of terms.}$$

$$\left.\begin{array}{r} 12 \times 37{\cdot}5 = 450 \\ 1 \times 37{\cdot}5 = 37{\cdot}5 \end{array}\right\} \text{extremes.}$$

$$\text{and } \frac{450 + 37{\cdot}5}{2} \times 12 = \pounds 146\ 5\text{s.}$$

144. Can you give any particulars of the cost of boring by machinery?

Mr. Vivian, C.E., of Whitehaven, who has had large experience in diamond boring, states that considerable reductions have been made in the price of diamond boring, and that quotations are now made on the merits of each case according to locality, strata, &c.

145. Give formulæ for finding the cost of a borehole.

To find the cost of a borehole:—Let c = cost; a = price for first step in depth; n = number of steps.

$$c = \{2\,a + (n - 1).d\,\}\,\frac{n}{2}$$

When n is not a multiple of a this rule is only approximately correct.

146. What systems of boring are in general use?

There are three systems of boring now generally adopted, two of which are true drilling processes, namely, spring-pole drilling and the steam percussion drill. The third method is by Diamond boring machine.

147. Which do you consider to be the best for deep boring?

For deep boring and hard rock the Diamond drill has certainly many advantages over the spring-pole method. Percussion drills are not suited to boring deep holes.

148. What is the method usually adopted for boring short holes?

Shallow holes are drilled without a spring-pole, the drills and rods being raised by hand. A top piece resembling a capstan head with four arms placed at right angles is attached to the upper end of the rods; and the rods are lifted and allowed to fall by two or four men (according to the nature of the strata and depth of hole) who stand opposite each other. They also rotate the drill by walking slowly round, taking one short step at each stroke. When the spring-pole is used, the up-and-down motion is communicated by hand or by a strap or rope attached to the pole, enabling the driller to use his feet.

149. Is there any rule as to the speed at which the drill should be revolved to ensure a round hole, and as to the intervals at which the rods must be withdrawn to put on the sand pump, &c., for extracting the sediment from the borehole?

No; these things depend entirely upon the character of the rock, and must be left to the judgment of the master borer.

150. Can you quote any authority upon rock-boring machines?

Dr. H. M. Chance, in the Report of the Second Geological Survey of Pennsylvania, says of the Diamond drill, "This drill has been largely used for prospecting purposes in the anthracite regions, and generally with good results. The claim frequently made that complete cores can be obtained showing the exact condition of a coal-bed, cannot be entirely substantiated, for the cores so obtained are not infrequently very imperfect, and are often little if at all better than loose fragments, and at times a considerable portion of the core is completely pulverised and lost. It is also claimed that the cores show the dip of the rocks, but as the rocks may be false-bedded or may exhibit a decided cleavage not coinciding with the bedding, it is not safe to base any important conclusions on deductions based alone on the apparent dip shown by the cores. The cost of drilling deep holes with a Diamond drill in rocks of moderate hardness is certainly much greater than by the rope-drilling method as practised in the oil regions, and the progress made is also much slower—the cores obtained may or may not be worth the difference in time and money."

151. Explain in short some of the principal tools used in boring.

The following are some of the principal tools used in ordinary boring:—The rods are usually about 18 ft. long, made of 1 in. iron, either round or square. Lengtheners vary from 6 in. to 5 ft. Chisels are generally 18 in. long, and vary from 2 in. to 3 in. in breadth on the face, which is made of the very best steel. The sludger is 3 ft. long, made hollow of wrought iron, with a clack at the lower end; this instrument is for the purpose of bringing up samples of the strata bored through. The wimble is of similar construction to the sludger, and used for the same purpose, but has no clack to it, and is open on the one side; boring through clay and soft metals is usually performed with this instrument. The "beache" is an instrument about 30 in. long hollow inside for about 18 in. up; the hollow inside is conical to force down on the top of broken rods to bring them to surface. Other tools of various descriptions are used in boring, but are too numerous to be described in this volume.

152. Supposing the boring completed, and it is decided to sink, what are the first points to be considered?

The first points to be taken into consideration are the size of pit and the form. Supposing there has been a proper section of the borehole kept by the man in charge, it will be known what quantity of water is likely to be met with and the nature of the strata through which the shaft has to be sunk. If a quantity of water is expected it will be for the mining engineer to decide the size of pumps and engines which will be required; also if the shaft has to pass through drifts, such as quicksands, &c., he must decide what kind of tubbing he will use for passing through the same, and whether it shall be of wood or iron, together with its size, strength, &c.

153. If it is decided to sink a circular shaft through ordinary strata with no great amount of water, the pit to be 12 ft. in the clear diameter when finished, describe in short the ordinary method of sinking to the stone-head.

If the pit is to be 12 ft. in diameter when finished, I would mark off on the ground a circle 14 ft. in diameter, and dig out the soil to a depth of about 6 or 9 ft., put in an oak crib of timbers 5 in. square at the bottom of the pit thus formed. Place another crib 3 ft. above this, supported on props, and a third and fourth, the top one being thus 3 ft. above the surface for tipping rubbish. Behind these cribs there must be backing deals 9 ft. long and 1 in. thick, and nail stringing deals inside cribs to support them, if necessary, to balks at the top. Proceed similarly for the next 6 or 9 ft., and so on till the solid is reached.

154. Describe the method of sinking a pit 14 ft. diameter through a drift of quicksand, &c., supposing it to be 50 yards in depth before a suitable place is found for the wedge ring to be put in, the tubbing to be of iron; also give the thickness and size of segments, &c.

I should carry the drum in this case to the surface, each segment of the drum to be 2 ft. deep, and twelve of them to form a course, and each segment to be strengthened by one horizontal and three vertical ribs. The flanges are such as are represented in figs. 8 and 9. The thickness of metal in the drum for this depth should be ·892 in. I would fasten the tubbing to the cutter; the cutter is simply a plate of cast iron, 1 in. or 1¼ in. thick in the upper part and sharp at the lower edge. The shoulder formed by the cutter and lower flange of the bottom course of segments is filled up with a bevelled ring of wood, as shown at A A, figs. 9 and 10; both the bevelled ring and cutter are riveted or bolted to the bottom course of segments by ¾ in. bolts. I would sink the pit down as low as possible for the quicksand, then erect a scaffold near the bottom of the pit, leaving a hole in the centre, so as not to interfere with the winding of water. On this scaffold I would build a drum to the

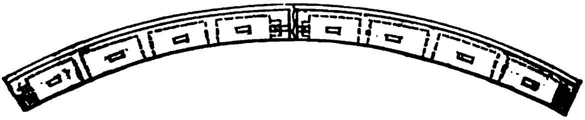


Fig. 8.—*Plan.*

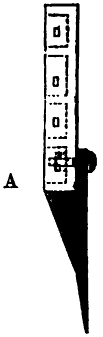


Fig. 9.—*Section through* B C. (See fig. 10.)

height of the surface, and bolt the segments together, as shown in fig. 10, having between the horizontal joints and vertical joints of the segments some well-dried ½ in. sheeting of pine; after these are all well screwed tightly together they will require wedging with some hard wooden wedges, which consist of small pieces of oak or pine. At the top of the pit I would have four strong balks, laid across each other to form a square; through each of these balks I would have two strong screws each 5 or 6 ft. long, which will be a total number of eight screws. From each of these hangs a chain at its lower end; these chains are fastened to the upper course of segments. If the ground at the surface be soft, short planks should be placed crosswise for the balks to rest upon, so as to spread the weight over as large an area as possible. The drum being built and the chains properly secured to it, the whole of the eight

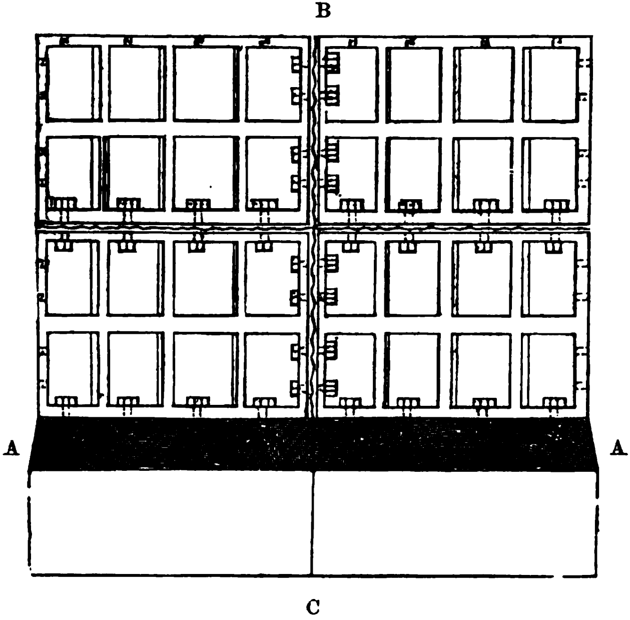


Fig. 10.—*Elevation.*
A = Bevelled ring of wood.

screws are tightened, and the scaffold at the pit bottom upon which the drum rested can be removed. Then the drum may be lowered down to the bottom by means of the screws; the chains will, of course, require lengthening as the sinking progresses. If it is found that the drum will not sink by its own weight when passing through the quicksand, whatever weight is required may be put on the drum by fixing another scaffold inside the drum near the lower end, leaving room between the scaffold and the bottom of the pit for the men to work, and a hole being left in the centre for winding the water and *débris*. On this scaffold bricks may be built round the pit, which will give an equal weight in every direction; but if the drum is found to stick on the one side, then a portion of the bricks may be removed from the one side to the other, or more bricks can be sent down from the surface. When the quicksand is passed through and the stone-head or a suitable place for the wedge-ring is reached, the bed for this ring must be made as level as possible, and with a little slope towards the side of the shaft. On this bed sheets of pine are laid for the ring to rest upon, so as to form a watertight joint. The wedge-ring is usually made of metal 14 in. broad and 8 in. in thickness, and 1 in. thick of metal is wedged and attached to the other part of the drum, as previously stated.

155. Can you give a good reliable formula for finding the thickness of metal tubbing for different depths and sizes of shafts?

Yes; the following formula is a good, reliable and accurate one:—

FORMULA FOR THE THICKNESS OF METAL TUBBING.

Let P = the pressure or vertical depth in feet,
D = the diameter of the pit, also in feet,
x = the required thickness of metal in inches.

$$\text{Then } x = \cdot 34 + \frac{P \times D}{3{,}800}$$

In this formula I have reckoned twelve segments to form a course, each segment 2 ft. deep, and to be strengthened by one horizontal and three vertical ribs.

156. Give a table worked out from the above formula that you can recommend as reliable.

The following is such a table, and I can vouch for its accuracy:—

TABLE I.

Depths. Yards.	9 feet diameter. Inches.	10 feet diameter. Inches.	11 feet diameter. Inches.	12 feet diameter. Inches.	13 feet diameter. Inches.	14 feet diameter. Inches.	15 feet diameter. Inches.
10	·411	·419	·427	·435	·442	·450	·458
20	·482	·497	·513	·529	·545	·561	·576
30	·553	·576	·600	·624	·647	·671	·695
40	·624	·655	·687	·718	·750	·782	·813
50	·695	·734	·774	·813	·853	·892	·932
60	·766	·813	·861	·908	·955	1·003	1·051
70	·837	·892	·947	1·003	1·058	1·113	1·168
80	·908	·971	1·034	1·097	1·161	1·224	1·287
90	·979	1·050	1·121	1·192	1·263	1·334	1·405
100	1·050	1·129	1·208	1·287	1·366	1·445	1·524

157. Can you give a table worked out by your formula in French measurements and English equivalents?

Yes; the table on the following page gives the required thickness of metal tubbing under various conditions, in French measurements and their English equivalents.

158. Describe the method of sinking through quicksand with the wooden drum or tubbing.

When quicksand has to be passed through which contains a great quantity of water, either running drums of wood or iron are used. By some persons the wooden drums are called brick drums, a great quantity of bricks being generally used to weight the drums down to make the cutters pierce the strata. The following are some particulars of their application. The drums are chiefly constructed of oak rings 6 in. wide and 4 in. thick, placed at intervals from 1 to 3 ft., according to the quantity of

TABLE II.

DEPTH.		THICKNESS OF PLATES.													
		9 ft. diameter. (2·7432 metres = 9 ft.)		10 ft. diameter. (3·0480 metres = 10 ft.		11 ft. diameter. (3·3528 metres = 11 ft.)		12 ft. diameter. (3·6576 metres = 12 ft.)		13 ft. diameter. (3·9624 metres = 13 ft.)		14 ft. diameter. (4·2672 metres = 14 ft.)		15 ft. diameter. (4·5720 metres = 15 ft.)	
Metres.	Yds.	Centim.	Ins.	Centim.	Ins.	Centim.	Ins.	Centim.	Ins.	Centim.	Ins.	Centim.	Ins.	Centim.	Ins.
9·1440 =	10	1·043 =	·411	1·064 =	·419	1·084 =	·427	1·104 =	·435	1·122 =	·442	1·143 =	·450	1·163 =	·458
18·2880	20	1·224	·482	1·262	·497	1·202	·513	1·343	·529	1·384	·545	1·424	·561	1·463	·576
27·4320	30	1·404	·553	1·436	·576	1·524	·600	1·584	·624	1·643	·647	1·704	·671	1·765	·695
36·5760	40	1·584	·624	1·663	·655	1·744	·687	1·823	·718	1·905	·750	1·976	·782	2·065	·813
45·7200	50	1·765	·695	1·864	·734	1·965	·774	2·065	·813	2·166	·853	2·265	·892	2·367	·932
54·8640	60	1·945	·766	2·065	·813	2·186	·861	2·306	·908	2·425	·955	2·547	1·003	2·669	1·051
64·0080	70	2·125	·837	2·265	·892	2·405	·947	2·547	1·003	2·687	1·058	2·827	1·113	2·966	1·168
73·1520	80	2·306	·908	2·466	·971	2·626	1·034	2·786	1·097	2·948	1·168	3·108	1·224	3·269	1·287
82·2960	90	2·461	·979	2·667	1·050	2·847	1·121	3·027	1·192	3·208	1·263	3·388	1·334	3·568	1·405
90·4400	100	2·667	1·050	2·867	1·129	3·068	1·208	3·268	1·287	3·469	1·366	3·670	1·445	3·870	1·524

water and pressure expected to be met with. Lags are bolted to these rings or cribs, 4 in. wide and 3 in. thick, their edges being well jointed to each other, so as to form a watertight casing, or nearly so; the diameter of the drum inside the cribs will depend on the size of the pit when finished. If the pit is required to be 15 ft. diameter when finished, and 18 in. brickwork put in, the cribs must be 18 ft. in diameter; or if 9 in. brickwork is put in, the cribs will only require to be 16 ft. 6 in. Around the bottom, on the outside of the drum, is bolted a leader, which is merely a plate of cast or wrought iron 2 ft. or 3 ft. deep and made taper or sharp at the lower edge. This drum should be made in the form of a churn, or cone-shaped, the larger end—that is, the end the cutters will be bolted to—to be at the bottom. This is shown in fig. 11, which is a section of the lags and cribs bolted together as above described. The length of drum or lags will depend on the thickness of the sand that has to be passed through before reaching the stone-head. The drum is placed in the pit, and the space between the cribs filled with brickwork to give it weight, the sand being then cautiously removed; the drum will slowly settle down, and being made cone-shape, the pressure of sand and water will help to force it down and to cut its way through the sand. Should the drum stick, more sand is taken out, and if it

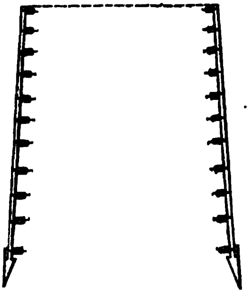


Fig. 11.

still refuse to move, more bricks are added to give it weight; this is usually done by placing bearers across it near the bottom, and there making a scaffold, with a hole through the middle, 5 ft. or 6 ft. square, to allow a hoppit or bowk to go through, the drum being then loaded with bricks. Having passed through the sand to the stonehead, a wedge crib must be laid for the brickwork to lie upon, or metal tubbing as before. In some cases a drum of wrought iron is used, made of boiler plates half-an-inch thick, riveted like the shell of a boiler; but as resistance to collapse is very slight, they are not recommended. In some instances, it is true, they have been successfully used, but in many others the pits have been lost through the collapse of this kind of drum.

159. Where there is quicksand containing a great quantity of water, would you adopt wooden or metal tubbing?

Such quicksand would be better passed through with the cast iron drums, commencing as before stated—that is to say, dig out the soil, &c., to the required diameter of the pit, allowing sufficient margin for timber and bricks, until the quicksand is reached; the top part of the pit to be lined with backing deals and cribs.

160. What care is necessary in plugging up the holes in the tubbing?

Care must be taken not to plug up the holes too rapidly, but to allow the air or gas to escape freely above the water, or most probably the pressure may cause the bursting of a plate or blow out the sheeting at the joints.

161. What method is usually adopted to allow the escape of confined air?

A pipe is sometimes fixed from the upper course of segments to the next length of tubbing above, and again from that to a higher part, and so on.

162. Where tubbing is put in to keep back or to tub out water, how do you ascertain the amount of pressure the tubbing has to resist?

As the pressure the tubbing has to resist will depend upon the head of water, it may be found in pounds per square inch by multiplying the head of water in feet by 62·5 and dividing by 144.

163. What form of shaft is, in your opinion, the strongest, and what kind is usually adopted in England?

The circular. There are several forms of shafts, but the circular form is the best; and, indeed, the only kind now sunk in England; and as so few other kinds are in use, it is hardly worth while giving details of them here. The size of shaft will, of course, depend upon the use for which it is intended; if winding, pumping and ventilation are to be carried out in it, there must be adequate room for these operations. In any case, a very tight-fitted shaft is very troublesome, and the extra cost for a little more room is amply repaid by the greater advantages it gives in getting work done, especially in connection with pumps.

164. Give a sketch of a shaft, in which winding and pumping operations are carried on, with cages, rods, &c., and, say, four sets of pump-stocks.

Figs. 12, 13, 14 are sketches of a shaft, cages, rods, pump-stocks, &c., fixed in when pumping and winding are carried on in the one shaft. In very deep pits, and even

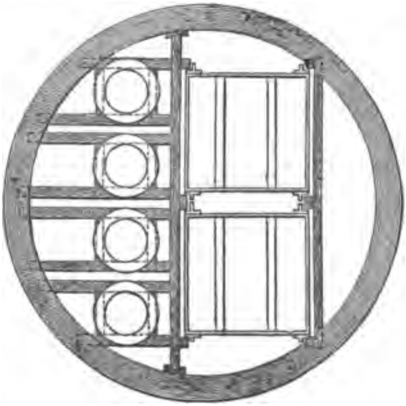


Fig. 12.

sometimes in pits only 160 or 170 yards in depth, there is often a large quantity of water to contend with, and four sets of pump-stocks are required, from 16 in. to 20 in. diameter each, to pump the water up the shaft, two being for the top lift and two for the bottom. When no shaft can be spared entirely for pumping purposes, and the shaft is but small—say, 11 ft. diameter—the four pump-stocks, cages, &c., would require fixing in, as shown in fig. 12, but this is a very defective arrangement, and should never be adopted, except under very pressing necessity. When a large quantity of water has to be raised, a shaft should be set aside for pumping alone; where this is not the case, should an accident occur in the shaft, either in the winding or pumping department, the damage will be considerable, besides a great loss of time. Fig. 13 shows a side view of a double deck cage for the above arrangement; fig. 14 the end view.

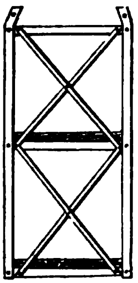


Fig. 13.

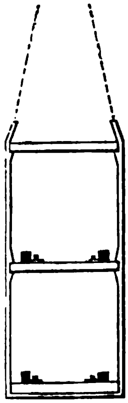


Fig. 14.

165. Explain what means you would adopt to keep the shaft exactly circular and straight while sinking.

This is accomplished by having eight plumb-lines, hung at equal distances round the pit from the last crib above, and kept about 3 or 4 ft. from the bottom. Having sunk sufficiently deep for another crib, the next thing is to level the floor for the crib to lie upon; then a staff the diameter of the pit is required, with a spirit-level laid on the upper side of it for the purpose of laying the crib exactly level; a niche is cut in the centre of the staff, and a plumb-line from the surface is hung down in the centre of the pit; if the pit is circular and straight, the plumb-line will cut the niche in the centre of the staff. The line is of copper wire, and wound up and let down by a bobbin, and can also be used for measuring the pit.

166. Which explosives do you recommend for sinking through hard rock, and for use in ironstone mines?

Guncotton and dynamite are increasingly used in sinking operations. Dynamite has several advantages over gunpowder—both for sinking and blasting—in ironstone mines. In the first place, it is safer, for a light or spark will not explode it, if the detonators or percussion caps are kept away from it; secondly, in sinking a pit which is very wet, the holes will not require "bulling" with clay, as dynamite acts equally well in water as in dry ground. Thirdly, the shot holes will not require drilling so deep for dynamite as for gunpowder, the former having a tendency to strike downwards or inwards. In ironstone mines and also in pit-sinking, a great deal of time and labour is saved in breaking up large blocks of stone, a charge of dynamite being put on the block with a handful of clay covering it; this, when exploded, has done its work better than by the ordinary method of breaking up the rock with wedges, it being blasted in large pieces, and the whole operation occupying only a few seconds, whereas, if performed by hand labour, it would have occupied an hour or two.

167. Describe the method of sinking and walling, &c., after the stone-head is reached.

When the stone-head is reached by either of the foregoing methods, and the pit made secure to the top, sinking is resumed in the usual way. The metals and rocks now to be passed through in the sinking have chiefly to be broken up and disturbed by blasting operations. This is accomplished by boring or drilling a hole or holes into the stone or metal for the insertion of gunpowder or other explosive. When a hole is intended to be drilled, a place is marked off with a pick, and one man sits down holding the drill in both hands between his legs, two more men with hammers striking the drill repeatedly; the man holding the drill keeps it regularly turned round until it is bored down its required depth. Where the pit is wet there is usually some stiff clay beaten round the top of the hole to prevent water from running into it, and to keep the hole as dry as possible while being drilled. If the sinkers find what they term a wet hole, means are then taken to keep the powder dry. The following are some of the methods adopted:—Sometimes a cartridge is made of calico to suit the diameter of the hole; it is then filled with powder, a proper length of fuse inserted, and tied at the top end with cord, then it is covered over with a thick coat of boiling pitch, which is generally mixed with a little tallow to prevent the pitch on the cartridge from cracking when cooled; paper cartridges are also commonly used, and, if well greased, are found to answer their purpose. When the shot-hole is very wet it is filled with stiff clay, and a round bar with a hole near its upper end, called a " bull," is driven in, the object being to case or line the hole with the clay and fill up all cracks and crevices in the sides of the hole through which the water oozes; after the bull is carefully drawn out again (by means of a cross-bar inserted through the hole at the upper end of the bull) the cartridge is placed at the bottom of the hole, and first a little dry hay or other soft material is put on the cartridge, afterwards metal or shale is put in, and should the strata be very hard, it is usual to put in small pieces of punned brick; then by means of a rammer struck down with a hammer, the hole is tightly stemmed or tamped up. Four or five of these shots and even more may be fired at one time, they being regulated by the different lengths of fuse. When the shots are ready to be fired, the sinkers, with all their tools, are drawn to the surface with the exception of two. The hoppit or bowk being again lowered, the sinkers at the bottom signal and receive a reply from the engineman that all is ready; they then apply lights to the fuzes, and signal to the engineman—"Pull up to the Top." They are then rapidly drawn up the shaft, and the gunpowder explodes as intended, provided all the holes have been properly managed. After the sinkers feel satisfied that all the shots have gone off, they again descend to the pit bottom and fill the loose material into hoppits or bowks, to be wound to surface. The *débris* being all removed, drilling is again commenced as before, care being taken that the pit is exactly circular and straight. The cribs or rings generally employed in sinkings are made of either wood or metal, but for an upcast pit metal ones, by all means, should be used. They are sent down the pit in segments, and bolted together at the pit bottom; if of wood, they chiefly consist either of oak or elm, but oak is preferable; the strength of timber generally used is 9 in. broad by 3 in. thick, the inside diameter of the ring depending upon the diameter of the pit. It is usual to place a water-ring, or what is termed a garland crib, a few feet above each seam of coal, or oftener, according to the quantity of water to be dealt with, as seen at A A, fig. 15.

When water-rings are put in, the brickwork above is shorn back, as seen in fig. 15, so as to allow the water that comes down the sides of the pit to run into it; the water is then conveyed from this ring into another ring lower down, or into a cistern or lodgment, as the circumstances of the case may necessitate. After the rings are duly laid in, the brickwork is commenced from the top of that ring to the under side of the ring above, either with dry bricks, bricks and mortar, or cement, unless there is a great quantity of water to be stopped back, when the bricks are set in cement, or iron tubbing put in as before stated, care being taken that small holes are left in the upper parts of the tubbing for the escape of air. The water is thus conveyed from ring to ring into a cistern or lodgment, as above described, instead of being allowed to run down to the pit bottom and to be ladled out by the sinkers. There is a pipe attached to the bottom of the cistern. In this pipe there is a stop-valve which is opened and shut by means of a lever; at one end of the lever a rope or wire is attached, long enough to reach to the pit bottom; when the rope is pulled it opens the valve and allows the water to escape out of the cistern through the pipe. At the other end of the lever a weight is attached sufficiently heavy to close the valve again when the rope is loosened. It is better to have ten or fifteen yards of hose piping, say about 2 in. diameter, to couple to the iron pipe by means of a union joint, so that it may be readily uncoupled when shots are to be fired. I

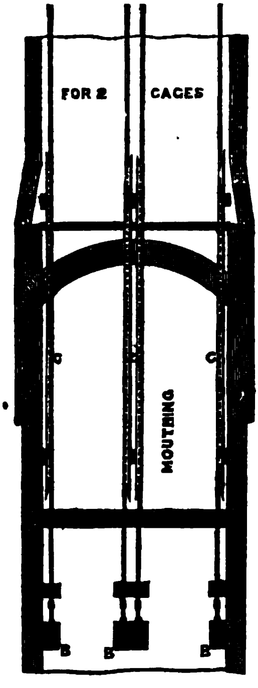


Fig. 15.

have had cases where it has been impossible for two men to keep the water out of a sinking by ladling, but by placing a cistern capable of holding about three or four hoppits of water, all the water above being conveyed into it, one boy at 1s. 6d. per day could easily do the work which the two men could not do by other means. By simply putting the end of the hose pipe into the hoppit and pulling the rope, the water runs into the hoppit, and it is immediately filled. By these means the pit bottom is kept dry, or nearly so. When there is a larger quantity of water to contend with than can be raised by the above system, it must be done by pumping. After the brickwork is made secure between both cribs, sinking operations are resumed as before. It may be the case that a few feet below the ring some soft metal or shale is met with, or even a thin seam of coal, and the under-clay or warrant beneath it may be very soft for six or seven yards in descent, then quite unexpectedly—just when the ring for another length of brickwork is being put in—you suddenly come to a very hard rock. It will not be wise to put the ring in at this point, as the shots in the hard rock will in all probability damage the ring and also the brickwork very considerably, and perhaps shatter them to pieces, as the rock may be sixty or eighty yards in thickness. Usually, when the thickness of the rock is not known, sinking is continued until it is ascertained. The pit may become dangerous by the sides above crumbling and mouldering when the ring above gives way. In this case another ring should be put in as soon as possible. There are several ways of overcoming this difficulty, the following being some of the best that have come under my notice:—As the whole thickness of rock is not passed through, but as far as it is possible to go with safety, a ring is only put in ten or twelve yards from the pit bottom, as the sinkers say, out of the reach of the shots. To form a bed for this ring to lie upon, twelve holes may be bored round the sides of the pit at equal distances, each hole being 2 ft. deep and 2 in. diameter: twelve iron plugs 3 ft. in length, and thickness to correspond with the diameter of the holes, are then driven in; the ring is laid upon these plugs and levelled as before, and bricking must be commenced as soon as possible to the ring above. When metal rings are used, eight planks are put beneath in octagon shape, as shown in fig. 16, to prevent any pieces of loose metal or rock the shot may throw up striking the ring and breaking it. The planks generally used are about 9 in. broad and 3 in. thick; and when there is a long length of brickwork hanging on the plugs, for the sake of safety eight holes are bored through the planks, as shown in fig. 16, for the purpose of suspending chains or rods to be attached by means of nut and washer at the under side. These chains are fastened to balks placed at the top of the pit, or in any other suitable position; they are then tightened by means of screws, and the brickwork is thus held until the rock is passed through. In sinking a pit which was recently under my charge, the difficulty referred to was met in the following manner:—As soon as I had put in a metal ring, and lined with brickwork to the ring above—the ring

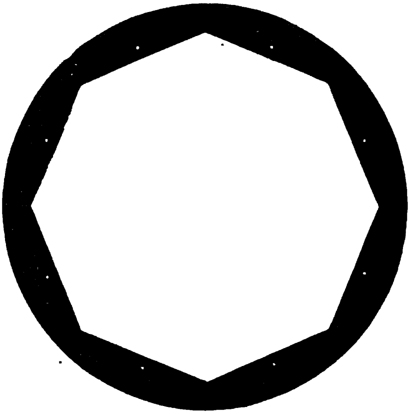


Fig. 16.

being laid on metal overlying a thin seam of coal, and the warrant under the coal to a depth of about 5 yards very soft—we came to a very hard rock and burr—extending to a depth of over 40 yards, but which we anticipated would only run about 6 yards. Sinking was carried on day after day in the expectation of getting through it; but when about 30 yards had been sunk through we were compelled partially to stop sinking operations, fearing lest the brickwork above would give way. As it would have taken a long time to plug a ring and hang it as before stated, I at once levelled a bed in the rock for a ring to lie upon at the pit bottom; then commenced brickwork and, putting in rings at suitable distances from each other, the brickwork all being made secure, sinking was again resumed. While the brickwork was being put in I had a wooden drum made, consisting of planks 21 ft. long, 9 in. broad, by 3 in. thick, and in each of these planks three holes were bored, one exactly in the middle, the others a foot from each end to allow ¾ in. bolts to pass through; the planks were bolted to three wrought iron rings made from 2½ in. by ⅞ in. iron; each ring was made in halves and fastened together by four bolts, as shown in fig. 17, AA; ¾ in. holes were punched in the rings at 12 in. apart, so that when the 9 in. planks were bolted to them, there would be 3 inches of space left for a man to get his hand through to screw the nuts on to the bolts. The rings, when put together, were thus 3 in. less in diameter than the pit, and having been sent down in halves, were bolted

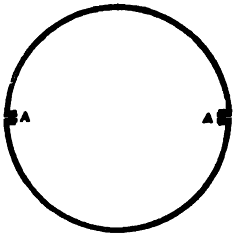


Fig. 17.

together at the pit bottom. The planks were then screwed to the inside of the rings, thus forming a casing round the inside of the pit 21 ft. high. The sinking was then continued through some very hard rock and burr, the brickwork in the shaft not being injured in the least from the effects of the shots. It was evident, however, when the drum was taken out, that, but for the protection it afforded, the brickwork would certainly have been shivered to pieces. Securing a pit on this principle is by far the cheapest, as the cost of making the drum is very little—the only joinery work required being to bore the holes—and the planks when brought up to the surface can be made into tramway sleepers and lids for colliers' use. The other system is a very expensive one for plugs and plugging, as well as for bearers and hangings, &c., and though the work be performed ever so well and substantially, there is always danger that the plugs and hangings may give way, with a consequent removal of the brickwork; but by the second method the men can work in confidence and safety.

168. Do you prefer to bore your shot-holes by hand or by machinery, when sinking or tunnelling through hard rocks, and why?

I should prefer rock-drills for boring the shot-holes in hard rock, as the work can be performed more economically and with greater rapidity.

169. What is the best rock-drill, worked either by steam or compressed air, that has come under your notice?

The Ingersoll rock-drill is adapted either for sinking or tunnelling, and is the best that has come under my notice. I cannot do better than quote the remarks of the judge at the American Institute, New York, 1873, which are as follows:—

The Ingersoll rock-drill is superior to all in the Exhibition for the following reasons:—

(1.) Its greater effective drilling power.

(2.) Its simple construction, there being but few working parts.

(3.) Its portability, both as to weight and adjustability of the tripod supporting the drill, allowing its use in very narrow cuts, especially in excavating for sewers.

(4.) The elastic cushions at each end of the cylinder protect the cylinder ends from injury when the piston is suddenly relieved from resistance, as when the bit passes through wide seams in rock.

(5.) Its having an automatic feed; thus giving it a steady motion in proportion to the power used.

(6.) Its great steadiness when at work, there being much of the absence of the jar and vibrations as expended in most other drills, which must be very destructive to their working parts.

(7.) Its great power in proportion to its size and weight, the force and rapidity of the blow being in proportion to the surface of the piston, in some *forty per cent.* in favour of the Ingersoll drill.

(8.) The facility with which all the parts can be renewed when necessary, all being made to conform to exact models.

170. If in sinking a shaft a feeder of water is met with 40 yards from the surface, and another 60 yards from the coal, what would you do with each?

I should put tubbing in to keep the water back.

171. Give the dimensions of a good hoppit or sinking bowk ordinarily used for sinking purposes, and what is a good shape?

Hoppits are made of iron, sometimes with a bow at the top, but usually with three iron ears riveted to the top for the purpose of hooking the chains that are attached to the end of the lowering or raising ropes; two iron rings are attached to the sides, about a foot from the bottom, for the purpose of tipping when full of bricks, &c. Hoppits are generally made cone-shaped, the inside diameter being at the top 3 ft. 2 in., and at the bottom 2 ft. 6 in., and the height 3 ft. 3 in.

172. If it is decided to wall the pit with bricks and mortar, give a rule for finding the cost of putting the brickwork in.

For bricking a pit with 9in. bricks and mortar the usual price per lineal yard is 1s. per foot for every foot of the pit's diameter; that is to say, if the pit is 14 ft. in diameter, the price would be 14s. per lineal yard; or the cost may be found by the following formula:—Let D denote diameter in feet, and L length or depth of brickwork in yards.

$$\text{Then } \frac{D \times L}{20} = \text{cost in pounds.}$$

Thus the cost of putting in 50 yards of brickwork 9 in. thick, the pit being 14 ft. diameter, would be $\frac{14 \times 50}{20} =$ £35. For every additional 4½ in. thickness of brickwork the price increases 4½d. per foot; thus, for 18 in. brickwork the price would be 1s. 9d. for every foot the pit was in diameter.

173. Can you give a rule for finding the number of bricks required to wall a shaft of any given diameter and thickness of brickwork?

By the following rule the circumference of any circle may be found, whatever the diameter may be, and the number of bricks to wall it: Multiply 3·1416 by the diameter, also by the depth in feet, then by the number of bricks required to build one foot, which is as follows:—

	Thickness. In.		Thickness. In.
5·333 for ...	4½	15·999 for ...	14½
10·666 for ...	9	21·332 for ...	18

By the above rule the quantity of bricks may be found for walling a pit any thickness and any diameter.

174. Can you give a good form of specification for sinkings?

Specification for sinking of No......Pit of the........... Coal Company Limited.

Diameter of shaft inside brickwork to be......feet.

To be sunk with a centre line and eight side plumb lines, so as to keep it exactly straight and circular.

Brickwork,......inches, set in mortar or cement as the manager may direct or order.

Rings or cribs to be put in by spirit level every .... fathoms, or as the manager may otherwise direct.

The water to be conveyed to the dip side of the shaft.

If the water exceeds 12 engine barrels per hour, an allowance to be made as may be agreed upon.

No shots to be put in within one foot of the side unless with the special consent of the manager.

All the walls to be carefully examined, dressed and made secure.

Work to be carried on by three shifts of eight hours each per day, beginning at 1 o'clock on Monday morning, and ending at 11 o'clock on Saturday night.

Not less than five men to be at the pit bottom in each shift, two of such men being experienced sinkers.

The contractors to employ and pay their own enginemen, banksmen and labourers, and to put the dirt, &c., which comes from the sinking wherever directed, within 70 yards from the pit mouth.

The contractors to be responsible for the conduct of their men, and for all accidents that may befall them, and for this latter purpose they must satisfy themselves as to the strength and sufficiency of all materials supplied them before using the same.

The contractors must furnish the manager, as the sinking progresses, with true samples and correct measurements of all the beds and strata the shaft passes through.

The contractors to provide their own powder and fuse, also candles and oil, and to return all tools, &c,, in good order, and to carry on the work regularly and without any undue loss of time, until complete, to the satisfaction of the manager.

The .... Coal Company Limited to supply all engine power and tools, also the material necessary for providing sufficient appliances for ventilation and safety, but the same to be put in by the contractors.

The manager to have full power to terminate the contract at any time if he is not satisfied with the way the work is carried on.

Payments to be made every ...., according to the measurement of work done, the .... Coal Company Limited retaining 10 per cent. in hand until the termination of the contract, with power to reimburse themselves for any loss or damage that may arise from nonfulfilment of contract on the part of the contractors.

Signatures for the ....
Coal Co. Limited ... ...
Signatures for the Contractors...

175. In sinking a pit, if large quantities of water are met with, explain how you would coffer it back with bricks and cement.

I would put an outward casing of bricks and cement or other mixture at least 18 in. thick, and brick and grout all the holes and crevices in the rock round the sides of the pit solid; then I would put another casing of 9 in. brick and mortar inside the coffering, so that in the event of any bearers or backstays requiring to be fixed for securing the conducting rods or pump-trees, this might be done without disturbing any of the coffering. A pit which is to be 14 ft. in diameter when completed, would in the first instance have to be sunk at a diameter of 18 ft. 6 in., or it may be stated as follows :—

Thickness of coffering, 1 ft. 6 in. × 2 = 3 ft.
Thickness of brick and mortar casing } 9 in. × 2 = 1½
Diameter of pit when completed... ... 14

Diameter at commencement ... 18½ ft.

176. Can you give a mixture of material cheaper and as good as cement for setting coffering in wet ground ?

The following is the composition of the material used in the coffering at the Lye Cross Pits, Rowley Regis. The length of the coffering was about 75 yards, and it is reported by Mr. R. Latham, the engineer, that this composition has proved a very effective mode of coffering water back. The cost of it is no more than the ordinary clay or soil :—

COMPOSITION.

15	cwt. of	black lime
5	„	white lime
5	„	coke dust (the newer the better)
5	„	clinker ashes from under engine boilers, but clear from finer parts commonly called "hess."
30	cwt.	

This mixture should be ground in a mortar mill and sent down the pit, to be used as soon as it is ground and mixed up.

177. Explain how metal tubbing in an upcast shaft may be protected from corrosion.

By lining the tubbing with a casing of brick and mortar 4½ in. or 9 in. thickness, as the circumstances of the case might require.

178. In sinking, if large quantities of water have to be coffered back with bricks and cement, does the strength of the coffering depend on the fineness of the cement used ?

Yes ; the Portland cement as it comes from the factory, is composed of an almost palpable powder, mixed with coarser grains which have but little adhesive quality. Mann's experiments have shown that in a trial of seven days the portions which pass through a No. 176 sieve (31,000 meshes per square inch) exhibit five times the adhesive strength of those which pass through a No. 103 sieve (10,600 meshes per square inch). The necessity of fine grinding is therefore obvious. In ordinary cement 45·6 per cent. is stopped by the No. 176 sieve, which is the finest that is made. The force of cohesion is much greater than that of adhesion, varying from threefold to tenfold. The adhesive force upon different substances, such as stone, brick, slate, marble, glass, &c., varies greatly. The degree of surface polish has less effect than one would think.

According to these experiments, the best test of Portland cement is its adhesive power. The No. 176 sieve ought not to stop more than 45 per cent. of the cement; the part which traverses the sieve should have an adhesive force of 95 lb., and the unsifted cement of 75 lb. per square inch.

179. What action does cement have on metals if embedded in it?

A brief memorandum of the late Mr. J. C. Trautwine, civil engineer, gives some experiments made to determine the corrosive action of hydraulic cements upon metal imbedded in them. The cements used were English, Portland, and Louisville; in addition to which, he tried plaster of Paris pure, and also mixed with equal measures of the cements. All were of the consistency of common mortar, and all were kept in an upper room during ten years, unexposed to moisture other than that of the indoor atmosphere. The metals were partly embedded in the pastes and partly projected from them. They consisted of cut iron nails, some of which were galvanised; smooth iron wire nails; brass in both sheet and wire; zinc in sheet; copper wire; and solid cylinders of lead three-eighths of an inch in diameter. The result at the end of ten years was that all the metals in both the pure cements were absolutely unchanged; and this was also the case with the plaster of Paris, with the exception of the ungalvanised nails, which had become covered with a thin coating of rust, as were also those in the mixtures of plaster and cement, but to a less degree. Mr. Trautwine concluded from his experiments that if dampness be excluded, both cement and lime mortar will protect for an indefinite time from injury all the metals employed in ordinary construction.

180. How is the tensile strength of cement tested?

Fig. 18 is a drawing of a machine for testing the tensile strength of cement and winding ropes. Most testers for this purpose have faults which interfere with the accuracy of results, owing to the vibration which is imparted to the machine during the process of testing, as extra weight and strain are being put under test. Sometimes it is done by means of a screw which lifts a lever, and sometimes by means of a movable weight which slides along a lever, similar to small weighing machines. This machine, which is called hydrostatic, has the weight—which consists of a long can into which a small stream of water flows—placed at the end of a lever; this enables the test to be applied in a very gradual and nearly imperceptible manner, without any vibration; in fact, the operator may sit down and watch the machine, after the tap has been turned on, until the fracture is effected. The height of the water in the cistern is indicated by means of a glass tube, similar to the water-gauge glass of

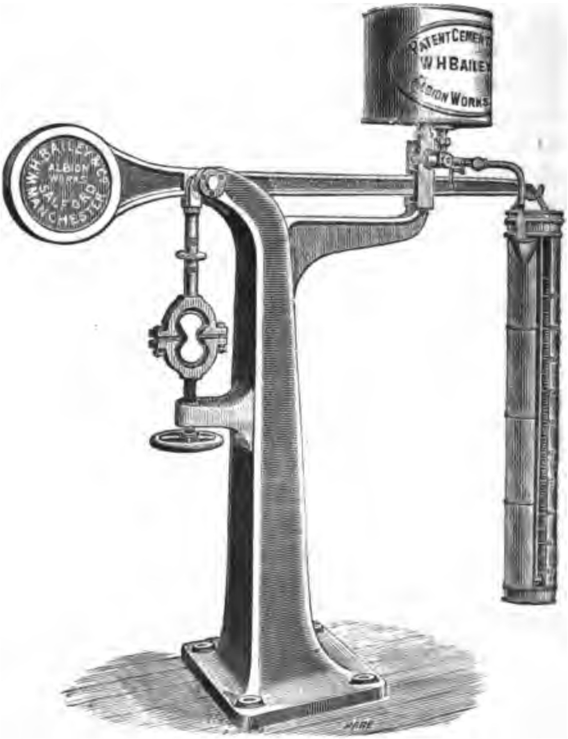


Fig 18.

a steam boiler, the graduation being painted down the can or cistern. When the material is broken, a small trigger, which closes the tap, prevents any further supply of water, and the breaking strain is indicated on the glass tube. This tester is known as Bailey and Reid's tester; and, although specially designed for cement, it can be readily altered to suit other materials.

181. Give a short description of sinking shafts by Herr Poetsch's patent freezing process.

The following description is from a paper read by M. Haton de la Goupillière before the Société d'Encouragement, upon the system of sinking shafts in watery soils and quicksands, invented by Herr Poetsch, by means of hollow iron tubes with cutting sabots, sunk in a circle round the well. Within these are placed other smaller tubes, pierced with holes, and through them a refrigerating liquid is forced in a continuous current until the soil all around is completely frozen, and thus the intrusion of the sand and water is prevented, so as to allow the sinking of the main shaft. The plan has been adopted with great success by Messrs. Siemens at their colliery at Schenkendorf, in Prussia, where the vein of brown coal is overlaid by a quicksand, making it very difficult to get at, for the shaft could not resist the enormous pressure of the water. By applying Herr Poetsch's system, however, a great wall of ice was gradually formed round the shaft, causing such a low temperature that the masses of sand before they arrived at the surface had to be thawed again. The quicksand was completely subdued, and a very promising colliery developed in consequence. [The freezing mixture employed is a solution of chloride of calcium, cooled to about 40 degs. C. below zero by a Carre's freezing machine. At Houssu, in Belgium, 39 ft. of quicksand, followed by 30 ft. of porous marl, very full of water, was operated on by this method, or a total thickness of 69 ft.; the depth from surface to top of quicksand was about 196 ft., shafts circular, 16½ ft. diameter, cost about £73 per yard.]

APPENDICES TO CHAPTER III.

Rope Boring.

The following description of the method of drilling for oil, generally adopted in America, is condensed from Mr. Carll's report to his Government. The drilling "rig" consists of a derrick fitted with bull-wheel and crown-pulley (sheave), for raising and lowering the tools; heavy mud-sills, with main-sills and sub-sills bearing the samson-post and jack-posts; a walking-beam, band-wheel and sand-pump reel, and foundation timbers and house for the engine. The "rig" costs from 400 dols. to 700 dols. in the oil country. Its cost in the anthracite regions will approach the latter figure. After the "rig" is erected, a pit 5 ft. or 6 ft. square is sunk to bed rock, and a wooden "conductor" box made of 2-in. plank 8 in. square inside, is set perpendicularly between the bed-rock and derrick floor, being stepped down a few inches into the solid rock, to fasten it immovably in place. The boiler is usually 20-horse power and the engine 12-horse or 15-horse power, reversible and controlled from the derrick by means of a pulley, which is geared to the throttle-valve by means of an endless cord. Another small rope also operates the reversing link, which drops back by its own weight. The band-wheel communicates motion to the walking-beam through the pitman, and the length of stroke is regulated by adjusting the wrist-pin in any one of the several holes in the crank. It also communicates motion to the bull-wheel through the bull-rope in running up the tools, and to the sand-pump reel by the friction pulley while sand pumping. This latter motion is effected by a lever, throwing the bevelled friction pulley into gear with the band-wheel. As the sand-pump descends by gravity, a brake-block is provided behind the pulley to check the speed at will by reversing the lever. The sand-pump line, a light ⅞-in. rope, is coiled on the shaft and passes up over the sheave. The sand-pump is commonly a plain galvanised iron cylinder with a steam valve at the bottom, or is made of wrought iron casing, and is provided with a plunger, not differing materially from the old style "sludger." The effective cutting blow of the tools is given by the weight of the bit, auger-stem and lower link of the jars. The "jars" are like two large flat chain links. Their function is to give the auger-stem and bit a decided jar on the up-stroke, to loosen the bit in case it should wedge fast in the hole The sinker bar is added simply to give the required force to the upward jar. It is never allowed to pound upon the drill. The temper-screw connects the rope and the walking-beam, and by it the tools are slowly lowered as the hole deepens. After drilling about 4 ft. it is necessary to run the screw up and re-clamp the rope, and while doing this the sediment is usually sand-pumped, and a newly dressed bit adjusted to the auger-stem. The cost is about 417 dols. for the single set for 5½ in. hole, and about 275 dols. additional for the jars, bits and reamer for boring an 8 in. hole. Norway iron is used for the pins, hammered iron for the collars and boxes, and the stems are made of the best rolled iron. Bits and reamers are made of Norway iron with large steel tips, constituting about one-half the tool.

Spudding.—The first 60 ft. cannot be drilled in the ordinary way. The method used is called "spudding." The augur stem and bit are attached by the rope socket to a short piece of cable (150 ft. to 160 ft. long), the other end of which is passed over the crown pulley and down to the bull-wheel, and a few turns taken round the bull-wheel shaft. The bull-wheel rope is thrown over, and the engine started. One of the drillers stands near the bull-wheel, with the loose end of the cable in his hands. A slight pull on this tightens the loose coils on the bull-wheel shaft which is rapidly revolving; the tools are raised, the rope is immediately slackened, the tools drop in the hole, another slight pull is given, and the process thus goes on until a sufficient depth is attained to enable the drillers to replace this motion by that of the walking-beam. When the bed rock lies at a considerable depth beneath the surface the wooden conductor is replaced by a wrought-iron drive-pipe. This is driven by a mall, which is raised and dropped upon the pipe, just as the tools are handled in "spudding." When the hole is sufficiently deep to admit a full "string" of tools, the drilling cable is passed over the crown pulley and coiled upon the bull-wheel shaft, and the other end riveted into the rope socket. The tools are then attached, the joints being carefully screwed up, the bull-wheel rope thrown off, and the tools lowered into the hole by the bull-wheel brake. The walking-beam connections are then made with the band-wheel by slipping the pitman on the wrist-pin and driving up the key; the temper-screw is suspended by a hook to the walking-beam, the walking-beam is thrown down by placing the pitman on the upper dead centre, the slack in the cable is taken up (by turning the bull-wheels until the jars are about two-thirds open) and the temper-screw is then clamped to the rope. The bull-wheel is then given several backward turns, to slack up the cable, and the tools are in position ready for drilling. As the tools rise and fall with the walking-beam, they are constantly rotated by hand by a short lever, inserted in the rings of the temper-screws; and the tools are slowly lowered as the hole deepens, by letting out the temper-screw. The driller relies solely upon the vibration communicated through the rope from the jars for his knowledge of how the tools are working. When the length of a screw has been run or the drill has been dulled by hard rock, the tools are drawn. The slack rope is first cleared of kinks, the bull-rope is then thrown in gear, and the bull-wheel brake applied and the engine stopped, just when all the slack rope is taken up. The clamps are then loosened, the pitman thrown off, and the walking-beam thrown up out of the way. The tools are then run up, but are stopped when the bit reaches the level of the derrick floor, where it is loosened by large wrenches, 3 ft. long; the tools are then run up clear of the hole, the bull-rope thrown off, the brake applied and steam shut off. The tools are drawn aside and held by a hook, and the bit removed and replaced by one newly dressed. While this is being done, the sand-pump is run up and down once or twice, by means of the friction gear and brake blocks, already described. After cleaning out the sediment in this way, the tools are again swung over the hole and the bit tightened up. The tools are then run down—controlled by the bull-wheel brake—the walking-beam connections made, the temper-screw clamped to the rope, and another "run" is commenced.

SHAFT SINKING IN THE ANTHRACITE REGION OF PENNSYLVANIA

The method of coal-shaft sinking in the anthracite region of Pennsylvania is described in the report of Dr. H. M. Chance's report, "A. C.," of the Second Geological Survey. "The average size of shafts now being opened in the anthracite regions is considerably larger than in former years. This change has resulted from three causes—(1) greater depths of shafts to open undeveloped coal in the deeper portions of the main basins, which necessitates (2) larger cross-section, to secure better ventilation for these more gaseous mines; (3) the policy now adopted of opening one large colliery in preference to two small mines necessitating better hoisting facilities. The width of shafts is usually governed by the length of the mine-cars, which ranges from 9 to 10½ ft.; hence the width adopted is usually 10, 11 or 12 ft. The length is governed by the number of compartments, and by the area of airway needed. The compartments are now made from 6 to 8 ft. broad, inside the buntons, or an average of about 6¼ ft. between the guides; hence the compartment measured between the centres of the buntons is usually from 7 to 9 ft. The length, therefore, varies from 16 to 20 ft. for a shaft with two compartments, 30 to 38 ft. for a shaft with four compartments (22 to 26 ft. being the ordinary length for three compartments), to 44 to 52 ft. for a shaft with six compartments. When this large number of compartments (six) is provided, two are usually used for an upcast airway, and for the pump-rods and column-pipe, and in some cases one is used with the hoisting compartments as a downcast, while at other shafts two extra hoisting compartments are held in reserve for future requirements. When the opening is located on ground covered by a moderate depth of soil or drift material, a rectangular pit is sunk at once to bed-rock. This pit is made from 4 to 8 ft. wider and longer than the proposed shaft dimensions, and is carried down one, two or three feet into the decomposed rock, or until a firm substratum is reached. It is then timbered up with a solid cribbing of large square timber—about 12 × 12 —which is either mortised or held firmly together by keys and gains. This timber cribbing is often replaced by a solid stone curbing, which is for some reasons decidedly preferable, especially as it can be used as a foundation for the head-frame. When the soil is of considerable depth and has a tendency to fill the pit by caving in, it is sometimes held in place by a temporary set of timbers until the permanent cribbing is inserted. At large shafts the cribbing is usually braced by buntons, which divide the shaft into the necessary number of compartments. After the cribbing is completed, a temporary sinking head-frame is built, either directly upon the crib or upon heavy beams resting upon it.

Drills and Explosives.—A comparatively small number of shafts have been sunk with steam or compressed-air drills. The old method of sinking by hand has still a firm hold in the anthracite regions, and many of the individual operators and companies consider it cheaper, and some more expeditious than sinking by power drills. It will not be necessary to describe the drills used, as nearly every style of percussion drill made in this country have been used in the anthracite fields for either sinking or tunnelling.

The objections to the use of power drills are:—

1. The cost of the drills, compressors and fittings.
2. Time lost in removing the drills before blasting, and in placing them in position for drilling.
3. Prejudices of the miners.

There is no doubt that, under proper management, quicker and cheaper work can be done in hard rock with the steam drill or drill worked by compressed air than by hand, but the difference is probably not so great as might at first be supposed. In sinking large shafts, the time lost in removing the drills might be lessened by working alternately on each end of the shaft, and removing the drills to the opposite end, under a shield of some kind, during the firing. Nor is it necessary to describe here in detail the hand method of sinking, which is in every respect similar to ordinary quarry work—a gang of three men, two strikers and the drill-holder working together. The number of gangs employed at once is of course governed by the size of the shaft. In shafts of the size now ordinarily sunk, from three to five gangs work together at once, and when quick time is to be made, three shifts, of eight hours each, are worked per day, otherwise two shifts are worked. The centre, or that portion of the shaft immediately under the head-frame, is kept in advance of other portions of the shaft to facilitate loading the bucket, and to act as a sump for the collection of water. The holes are drilled from 3 ft. to 6 ft. apart, depending upon the nature of the rock, its dip, cleavage, planes, &c., and are now usually fired simultaneously in groups by an electric current. "Rend rock" and other varieties of the higher explosives are used in hard rock, but in soft slate better results are obtained with ordinary black blasting powder. The dip or cleavage of the rock often governs the position of the lowest point or sump, and, in order to obtain the best results in blasting, it may sometimes be advisable to move the head-frame or to erect an auxiliary frame, in order to have the lowest point (sump) immediately beneath the sheave. A plumb-bob is suspended from each corner of the shaft, either from the flooring or from a beam laid across the cribbing, to guide the miners in squaring the corners and sides. After firing each blast, a gang of labourers immediately descends to load the displaced rock, while the miners resume drilling.

Compartments.—All hoisting shafts are divided into compartments. At large collieries two compartments are usually used for raising coal, a third for the pumps or pump-rods and column-pipe, which is also often used as an upcast airway, and a fourth held in reserve for lowering timber and raising and lowering the miners, &c. Two compartments are occasionally used in common as an airway and for the pumps, and sometimes two compartments are held in reserve for lowering timber, &c., and for raising and lowering miners. When the whole of the shaft is used as a downcast, a very small compartment answers for the pump-rods and column-pipe, and the practice is to divide the shaft into two large compartments for winding coal, men and mine supplies, and one small compartment for the pumps, column-pipe, &c. A reserve hoisting plant is sometimes placed at the second opening and used exclusively for raising and lowering the miners and mine timber, &c. (as at the Exeter Colliery), this opening being at the same time used as an upcast, the hoisting shaft being used as a downcast, or as both upcast and downcast. The size of the compartments depends upon the size of the cage, which is necessarily governed by the size of the mine car. The guides are in some cases simply bolted (by bolts with countersunk heads) to the buntons, but a better plan is to let them into gains cut on the bunton, as by this plan heavier guides may be used, and the bolts are subjected to less strain.

Practical Details—Sequence of Operations.—When the location and size of the projected opening have been determined, and staked out on the ground, an open pit is commenced in the loose earth and sunk as such to the bed-rock. This pit is usually made from 4 to 8 ft., or more, larger than the size of the shaft, thus allowing from 2 to 4 ft. on each side for masonry or timber cribbing. When the loose earth or soil is deep, or when it is of a sandy character, or too soft to sustain itself, a light temporary crib is necessary (which is sheathed if the material is loose sand or quicksand) to sustain the walls until bed-rock is reached and the permanent stone curbing or timber cribbing built. While the pit is being excavated preparations are made for erecting the hoisting engine and boilers. The winding (sinking) engine is best located opposite one end of the shaft and not opposite the side, for if the latter location is chosen it will interfere with the erection of the permanent plant, and it will be impossible to shift the head-frame without throwing the rope out of line; again, with the engine opposite one end of the shaft two head-frames may be erected, and both buckets may be operated from the drum without the use of deflection pulleys. As the load to be lifted during the sinking operations is comparatively light—from 1,000 to 3,000 lb.—the engine foundations are not massive. In some cases a timber crib, ballasted with stone, answers every purpose, but under ordinary circumstances a rough stone foundation of moderate depth, or a combined stone and timber seat will cost but little more and give better results. The engine foundations having been staked out, a suitable pit is dug, the foundations are laid, and the sinking engine and drum set up while the shaft-pit is being dug and cribbed. When the pit is cribbed with timber, no stone curbing being used, the timbers are set "skin to skin;" the frames are securely mortised together and held in place by keys inserted in gains cut in each frame immediately opposite each other. For cribwork curbing, square timber 10 in. by 12 in., 12 in. by 12 in., or 12 in. by 14 in. is commonly used, but larger timber has been used at a few shafts. Enough of the decomposed rock at the bottom of the pit is removed to expose a hard firm floor on which to set the cribbing. The sides are braced by heavy buntons of square timber, which divide the shaft into compartments. These are sometimes not inserted when the cribbing is built, but the shaft is left clear of all such obstructions until finished. In large shafts the buntons in the cribbing are placed only 1 ft. or 2 ft. apart, and in yielding ground are sometimes raised in juxtaposition, "skin to skin." When the pit is deep the loose earth is sometimes raised by a windlass; but the method usually adopted is either to cart it out through a cut or to shovel it upon stagings, from which it may either be shovelled or wheeled away in barrows. When a stone curbing is erected instead of a timber cribbing, the process is precisely the same; but it is necessary to place inside of this timber framing (or buntons) to carry the keeps or wings, the cage guides, steam and column-pipe, pump-rod guides, &c., &c., but these timber frames are then set some distance (usually from 3 ft. to 8 ft.) apart. They are sometimes built into the masonry, but are frequently inserted afterwards. When the pit has been completed and the cribbing or curbing finished, the work of sinking through the rock may be commenced as soon as the sinking head-frame is built and the engine and boiler setting completed. The head frame is best built on heavy sills laid across the shaft and resting on the cribbing or curbing. These sills may be bolted to the cribbing to secure greater rigidity, and the frame itself is securely bolted down to the sills. The head-frame being completed, the rope wound on the drum, the engine and boiler connections are made, and the work of sinking through the rock begins. When the rock is naturally soft and has a tendency to slip, or when a considerable thickness of partially decomposed rock is passed through before striking solid strata, the work of timbering must be carried downward *pari passu* with the sinking, but when the strata passed through are hard and self-sustaining, the opening is usually left untimbered until the sinking is completed; and under such conditions the timbers are set at a considerable distance apart, their office being not to support the sides so much as to carry the guides, column-pipe, pump-rods, &c. When the timbering must be carried down with the sinking, it is usually necessary to set the frames at short distances apart. Two methods of holding the frames in place are in use :—(1.) By wedging them fast by wooden wedges driven in between the frame and the rock. (2.) By making the end or side pieces longer than the width or length of the shaft, and setting them in notches and wedging them in place. When the timbers are to be wedged fast, they are held in place, either by props or are suspended by chains or bolts from the set above, until firmly fastened. In driving the wedges two objects are accomplished:—(1.) The timbers are securely fastened. (2.) They are brought into a vertical line with the sets above, so that the shaft guides shall be perfectly perpendicular and straight, and the compartments of equal size throughout. When the timbering is inserted after the completion of the sinking, the process may be reversed, the timbering being commenced at the bottom and finished at the top. Water:—When only a small amount of water is encountered, it is usually allowed to collect in a sump immediately beneath the head-frame, and is then raised in the bucket used for hoisting rock, but when numerous heavy feeders are encountered, a steam (sinking) pump is necessary. It will not be necessary to describe here any of the forms of pump used for this purpose, as almost all kinds of steam pumps have been so used. Rod-pumps have been used in the past at a few sinkings, but they are not used at present for this purpose.

Ventilation.—When the sinking is of moderate depth, a fire burning in one corner of the shaft will supply ample ventilation. If the powder smoke does not clear away in a few minutes, a bundle of straw is taken down and burnt at one end of the shaft and a few pails of water thrown down at the other end. When greater depth is reached, or if the shaft is of small cross-section, ventilation is accomplished either by a steam jet, by a fire drawing up into a large board pipe, or by a fan. When a fan is used, a portion of the shaft—often one compartment—is bratticed off, or a large board pipe is carried down to the bottom at one end of the shaft, and the fan is used either as a blower or as a suction fan. A suction fan will clear the smoke out more quickly and admit the light sooner than a blower; but by blowing, good air is obtained at the bottom immediately after firing. The fan sometimes takes power from the winding engine (when the drum is provided with friction gear), sometimes from a small engine that may be used for other purposes, and is sometimes turned by hand. Fans used for this purpose are usually from $2\frac{1}{2}$ ft. to 6 ft. in diameter. The men are commonly raised and lowered on the bucket, but when the shaft is timbered as it is being sunk, ladders are usually provided.

Development.—When the shaft has reached and passed through the bed to be worked, a small excavation is made beneath the two hoisting compartments for a timber frame on which the carriage is to rest. On the dip side of the shaft a sump is excavated in the coal, and at the same time gangways are being driven to the right and left to open up the bed for mining. But before much development work can be done it is necessary to erect the permanent head-frame, hoisting engines, boilers, fan, &c. It is usual to proceed with the erection of the winding machinery, hoisting engine and boilers while the shaft is being sunk through the lower third or fourth of its depth, so that all will be in readiness for the work of development as soon as the shaft is finished. The erection of the permanent head-frame may be completed before the removal of the temporary structure, so that there is no stoppage from this cause. This can be done at large shafts, by erecting the temporary head-frame over the portion of the shaft to be used as an upcast airway, or by making it so small that the permanent structure can be built around and over it. When the permanent hoisting plant is completed, the work of development is prosecuted night and day until one of the gangways is holed through into the second opening, and until a sufficient breasting area has been opened up to satisfy the operators. As the work of development proceeds, or in many cases as soon as it is commenced, it becomes necessary to erect the permanent ventilating machinery—which is now usually a fan of the Guibal type—and to make preparations for the permanent pumping plant. The hoisting compartments of some shafts are lined with boards from top to bottom; but if these are to be used together as a downcast airway, there must be free communication between the two compartments, and one side at least must therefore be left open.

Speed of Sinking.—The speed of sinking, including the time required for timbering and all stoppages, may be considered to average from 200 to 300 ft. per year; and while many shafts have been sunk at a considerably faster rate, the above figures may be considered to represent the average progress of hand-work. The adoption of steam drills, or drills worked by compressed air, certainly increases the speed of sinking through hard rock; but in slate, shale, and soft sandstone, better time can probably be made by hand. The use of steam drills is decidedly objectionable—especially when the shaft is timbered as sinking progresses, or when the rock is of such a character that the heat of the steam causes it to "melt," soften, or slip.

CHAPTER IV.

TUNNEL OR STONE-DRIFT DRIVING.

182. Explain the term tunnel.

A tunnel is a subterranean passage made in order to carry a canal, railway, or road through.

183. Name a few cases in which tunnels have to be driven.

It is often necessary to drive a tunnel, or, as it is termed in mining, stone drift, through rock or strata overlying or underlying the seams of coal, &c., sometimes to connect two seams, or two shafts, or where the seams of coal, &c., have been dislodged by a fault. It is also required when a permanent railway has to be carried through a hill or mountain, and at other times tunnels are driven into hill-sides for the purpose of proving and working mines, or for draining off water.

184. Where is a railway tunnel usually commenced?

A railway tunnel is always commenced from both ends, and when it is of great length, shafts are sunk at intervals from the surface to the depth of the tunnel, and excavations made in both directions from the bottom of the shaft. The cost of sinking these shafts is about £5 per yard in England, taking the average in ordinary ground, and where not much trouble is given by water.

185. Give a short description of the method of driving railway tunnels.

It is customary to commence by working a small heading or passage, 6 to 7 ft. high, from shaft to shaft, through the whole length of the tunnel, the top of the heading being level with that of the intended tunnel. This fixes the centre line of the tunnel, and the excavation proceeds by the enlargement of this smaller passage. As the work goes on, the roof and sides of the tunnel are supported by boards and bars. This is seen in fig. 19,

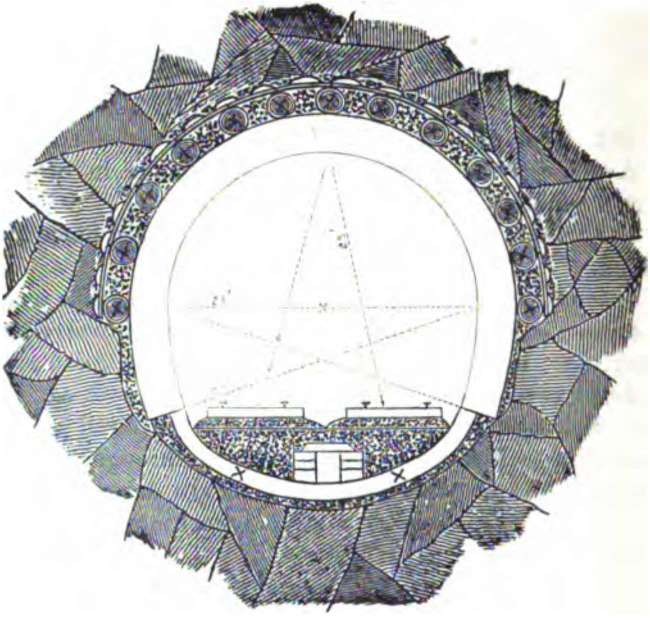


Fig 19.

which shows a section of a tunnel arched, with a preliminary timber support to the roof and sides to protect the workmen until the brick arch is completed. When a certain length of the tunnel has been supported in this way, arching or centreing is commenced, being constructed as in building arched bridges; the roof and sides are then supported either by stone or brickwork built as arching.

When a tunnel is very long, permanent shafts are sunk for ventilation. These are generally made circular in section, and about 10 ft. in diameter. Shafts that are made merely to facilitate the construction of the tunnel are made only wide enough to allow the buckets, used to convey away the excavated material, to pass one another, and are built up when the tunnel is completed. Tunnels are always arched above, and more or less curved at the sides, so as to resist the downward and inward pressure. If the side pressure is severe, and the walls when built show any sign of bulging; or, if the foundations of the walls are in weak ground, an invert should be introduced; this is a very simple operation, the greatest difficulty being with the water, which naturally collects in the excavation. The invert is made and kept to form by means of a frame made to the shape of the back of the brickwork. Fig. 19 is a section where an invert is required, showing the tunnel arched, and the preliminary timber supports to the roof and sides to protect the workmen until the brick arch is completed. In building the invert the brickwork should be commenced in the centre and worked towards the side walls.

186. How would you draw the bars from over the arching when completed?

Striking the props, which have supported the bars from the top sill, is commenced first with the crown bar. If the weight has not been very severe and ample allowance has been made for "drop," the bar will have a little play and will fall upon the brickwork of the arch. It then can be drawn out by means of a small crab; if it sticks a little it is drawn with a "dog" or "devil"—a stout bar of iron about 6 ft. long, having a slightly hooked claw at one end, which end is inserted under the bar, and by using the brick toothing as a fulcrum the bar can be levered forward. Generally, the bars are drawn with what is called a "dog and chain," (fig. 20), which consists of a piece of chain 6 ft. long with a hook at the end of it; this is passed round the bar and hooked into a link, and the end of it put into the link of the "dog." The point of the lever is pressed against a prop as a fulcrum and the bar is drawn out. If, however, the pressure has been so great that the bars have sunk and become tightened, the full thickness of the brickwork of the arching being with difficulty built under them, they are drawn by means of strong screws.

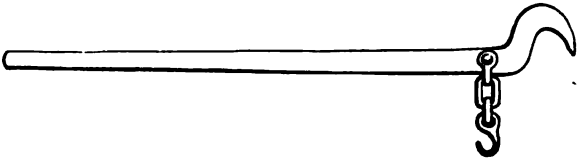


Fig. 20.

187. In lining a railway tunnel what thickness of brickwork should be put in ?

That will depend greatly on the strength and nature of the strata through which the tunnel has to pass. In some cases a mere lining of about 9 in. work is sufficient; in others lining from 2 ft. to 4 ft. thick may be required. When the rock is of a strong character a slender arching will suffice, but when it is of a tender and loose nature and the pressure may be great, the thickness or strength of the arching must be proportionate. It is the practice of some colliery managers, when arching their underground roadways, to commence with a certain thickness of lining and to keep to that thickness throughout the length of the roadway, no matter how much the strength or character of the rock varies; consequently in a very short time the weak places of the arching show themselves, the brickwork being crushed in; this remark indeed, does not apply only to underground roadways in mines, but sometimes also to tunnels for permanent railways and canals.

188. What is the crushing pressure for bricks ?

A first-class machine-pressed brick—say Staffordshire blue-pressed—will withstand a pressure of 350 to 450 tons per square foot. Soft bricks will crush under a pressure of from 30 to 50 tons. Blocks or masses of brickwork crush under much smaller pressures than single bricks, and if set in cement not hard will crush under from 25 to 35 tons per square foot, but set in Portland cement nine months old they will withstand a pressure of 300 to 400 tons.

189. How would you drive a tunnel which has to pass through very hard rock ?

Such tunnels should by all means be bored by machine. See figs. 21 and 22. The small heading may be driven first as before explained, or the tunnel may be at once constructed to its full size; the work will, however, be pushed on more expeditiously by adopting the former method, for one set of machines can be set to work in the small heading, while another set is enlarging the tunnel behind.

190. What qualities should be looked for in a machine for tunnel driving ?

Several points should determine the choice of a machine :—(1.) The first cost of the machine and tunnel cars. (2.) The amount of work the machine will perform in a given time. (3.) The time occupied in setting, &c. (4.) Whether the machine will bore at any angle. (5.) The simplicity of the working parts and the amount of skilled labour required in working. (6.) The number of men required to attend to each machine. (7.) Whether all the working parts of the machine can be easily renewed, and at little cost. (8.) The portability of the machine.

191. What machine, in your opinion, best fulfils these conditions ?

The Ingersoll rock drill. My reasons for recommending it are :—(1.) Its first cost is considerably less, in proportion to the amount of work it will perform, than that of any other drill I know; the average rate of progress varies according to the diameter of the hole to be drilled, but supposing the hole to be 3 in. diameter, which is an ordinary size in tunnelling, the Ingersoll will give 600 blows per minnte, with 30 to 40 lb. of steam or air pressure, and will penetrate granite at the rate of 19 in. per minute. This rate of progress, the patentees claim, exceeds that of any other drill. (2.) Its portability—both as to weight and adjustability—makes the drill very convenient to handle, and under the most difficult conditions it can be set to work in a very few minutes; its whole weight only averages from 120 to 400 lb.; and it can be set to bore a hole at any angle. (3.) It has either hand or automatic feed, and is simple in construction, there being fewer working parts than in any other drill; one man is sufficient for each machine; and, in some cases, one man can attend to two machines, the automatic feed giving it a steady motion in proportion to the power used, and elastic cushions, which are placed at each end of the cylinder,

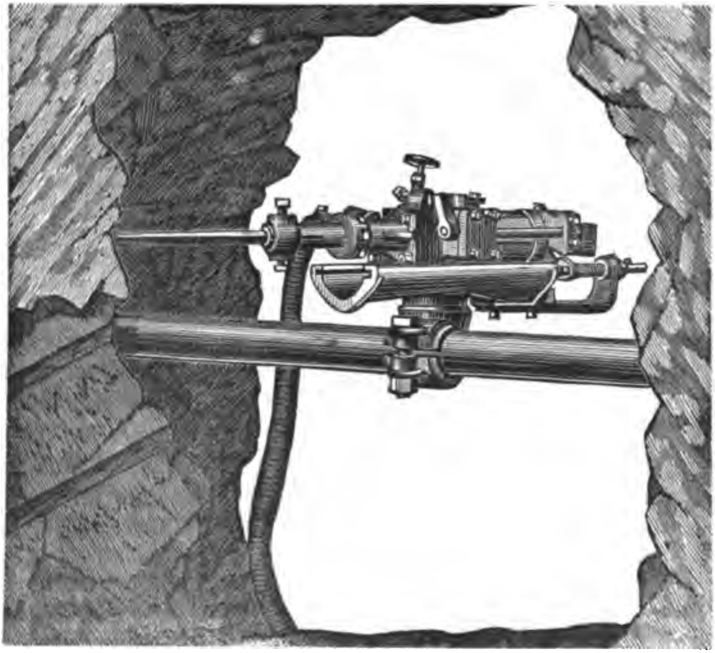


Fig. 21.

protect the cylinder ends from injury when the piston is suddenly relieved from resistance as the bit passes through wide seams in rock. The working parts can be easily renewed at little cost, as they are made to regular patterns. Recently an improved type of the Ingersoll drill has been brought out, in which the mechanism is greatly simplified, the efficiency increased and the consumption of motive fluid decreased.

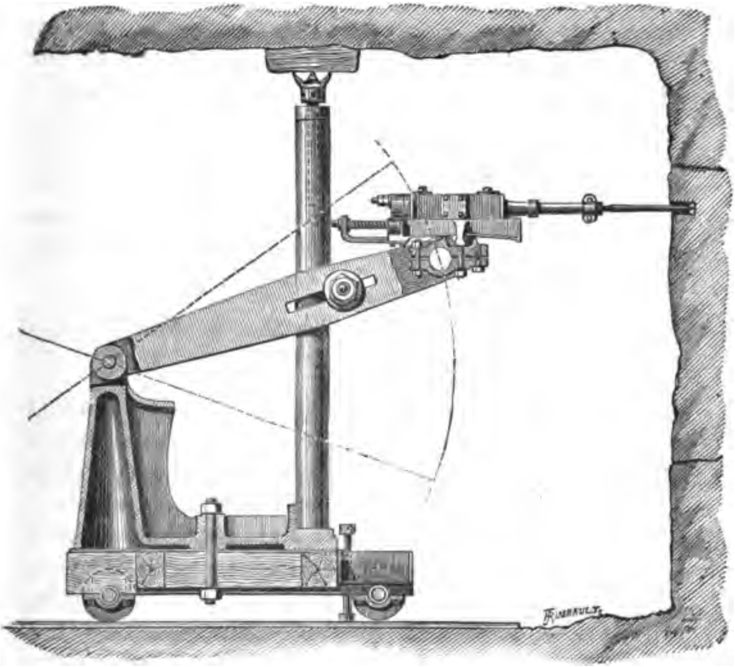


Fig. 22.

192. How would you drive the small headings by machine labour?

When small headings are being driven by machine labour, the machine can be attached, either to a column, as shown in fig. 21, or to a small tunnel car, fig. 22. This car is adapted to small headings, and is so arranged that one man can easily raise or depress the arm carrying the machine; the car being placed, the column is allowed to take a vertical position, after which it may be pushed, when necessary, from one side of the tunnel to the other on the turntable, and screwed tightly to the roof of the heading. The car consists of a small carriage, together with the column, which, when fixed in position by means of the ordinary tunnel screw, forms a stretcher bar, and being immovable, provides the best fixing possible to any part of the tunnel. It is inexpensive, and is found to effect a great saving in time, for the machine may, by means of the projecting arm, be run out and put to work, irrespective of *débris*. It is found in practice that there is no better method of fixing drilling machines than on the principle of the stretcher bar. As before stated, the column can be made to suit any size of heading or shaft; it extends from top to bottom in driving headings, and from side to side in shafts.

193. Explain how you would use the machine for enlarging the tunnel to its full size.

A machine car is constructed which is specially adapted for tunnels of large dimensions, and also for enlarging a tunnel to its full size; four or less drills can be fixed to this car by means of a clamp on the stretcher bar, which is raised or depressed at will by screws, and then tightened into position. This car can be easily adjusted, the arms carrying drills with a sweeping motion on the car, from side to side, as well as backward and forward, thus enabling the machines to be brought up to the working face irrespective of any *débris* that may be at the side. Each machine can then be moved and adjusted separately by means of the clamp which moves round about the arms of the car, and allows the machine to be placed at any angle and in any position. When it is not desired to go to the expense of tunnel cars for large tunnels, the plan is adopted of driving a heading in the upper part by using the drills on columns and following after by clearing away the lower part (or bench) by using drills on tripods. This is called the heading and bench system.

194. Is steam or compressed air best for driving the machines?

Compressed air is best for tunnelling; steam is not suitable, as it is a great impediment to the ventilation, has injurious effects on the roof and sides of the tunnel, and makes it uncomfortable for the workmen.

[For other questions on compressed air, see Chapter X.]

195. Explain in short how you would arrange your shot-holes in tunnel driving.

In tunnel driving, shot-holes are generally placed at regular intervals apart, and should be bored as nearly as possible to the line of least resistance; after the whole number of holes required at the face are bored, the car, with the machines, is run back, and the holes charged; the holes intended to unkey the face—whether in the centre or near the floor, which latter are termed holing shots—will, of course, require the heaviest charges, the resistance to these being very great, as they have to fracture or joint the rock for the other shots; the more complete the unkeying the better will be the results from the shots which follow.

196. Which system of shot-firing do you prefer, the ordinary system of fuze, or by electric exploders? Give a short description of the instrument you would recommend for firing by electricity.

I prefer firing shots by electricity, and when there are not more than four or five shots to be fired at one time, I recommend a small magneto-exploder as being a practical and useful instrument. Messrs. Davis and Son, of Derby, manufacture a very suitable instrument; it has six magnets, and its dimensions are only 5 in. by 3⅞ in. by 4 in., and its whole weight being but 4¼ lb. The exploder illustrated below is a powerful machine, capable of firing a considerable number of shots simultaneously, and is much used for pit-sinking, submarine mining, and excavating large masses of rock. When there are a great number of shots to fire I should recommend the dynamo tension exploder, by which any number can be fired simultaneously.

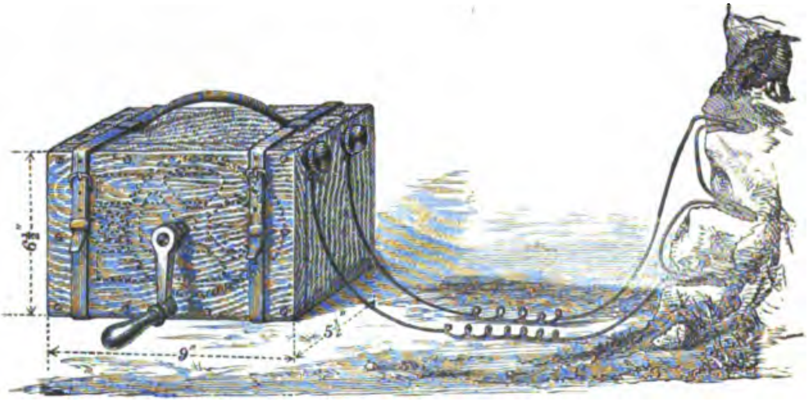


Fig. 23.

[For other questions on shot-firing, see Chapter VIII.]

197. Explain the system of driving stone drifts into mountain sides to recover coal, as is done in South Wales and the United States.

In South Wales, a large area of coal is wrought by drifts driven into the mountain sides, and a still greater portion in the United States, shafts being sunk from the summit of the mountain to the level of the seam, for ventilation, &c.

198. What are the usual sizes and sectional areas of stone drifts driven in underground workings in England, and what systems of labour are adopted — manual or machine?

The sectional areas of stone drifts vary according to circumstances and the distance they may be from the pit. In some cases they are driven wide enough for one set of tram-rails, in other cases for two sets, and, again, three sets are sometimes required. The usual size in collieries, however, is 7 × 6 ft. If the drifts are driven through hard rock, the work of driving will consist wholly of blasting, performed either by manual labour or machines; if by machine, the kind used will depend on—(1) the distance the drift has to be driven, and whether it will pay to employ an expensive machine; (2) the expense of pipes, &c., to convey compressed air to the point where the drift has to be commenced. When an air-compressor can be fixed, it will be found more useful and more advantageous than steam, the objections to which have been before stated.

199. Supposing a rock-drill for boring the shot-holes is decided upon, describe the driving of the tunnel.

The first series of holes is bored in the face of the drift near the floor (A, fig. 24), and are termed holing shots.

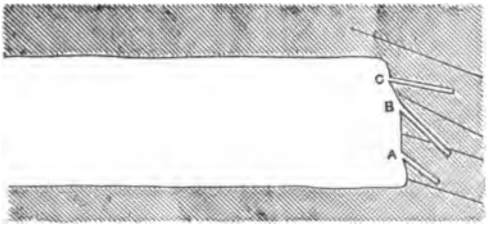


Fig 24.

After these have been charged and fired and have done their work, other holes are bored, as shown at B C. If there is no air-compressor available or it is deemed too expensive to carry air-pipes, &c., to the stone drift, then boring operations will have to be performed either by manual labour pure and simple, or with machines worked by hand. Machines worked by hand are far more suitable and economical, both as regard rapidity and effectiveness, than boring by hand labour only. Without hesitation I should say the best kind of boring machine is Macdermott's patent rock and coal perforator.

200. Give a short description of this machine.

It is very simple in construction, with but few working parts, and is illustrated by fig. 25, with improved feed-box and telescopic standard. It is one of those machine tools which have done so much to increase and cheapen production in every branch of industry. It can be worked by one man, but gives a result equal, on an average, to the hand labour of six or eight men, as tested in the different strata connected with the coal measures. It will drill a hole, either at the top or bottom, or at any intermediate point of the drift, and at any required angle; it is, therefore, invaluable

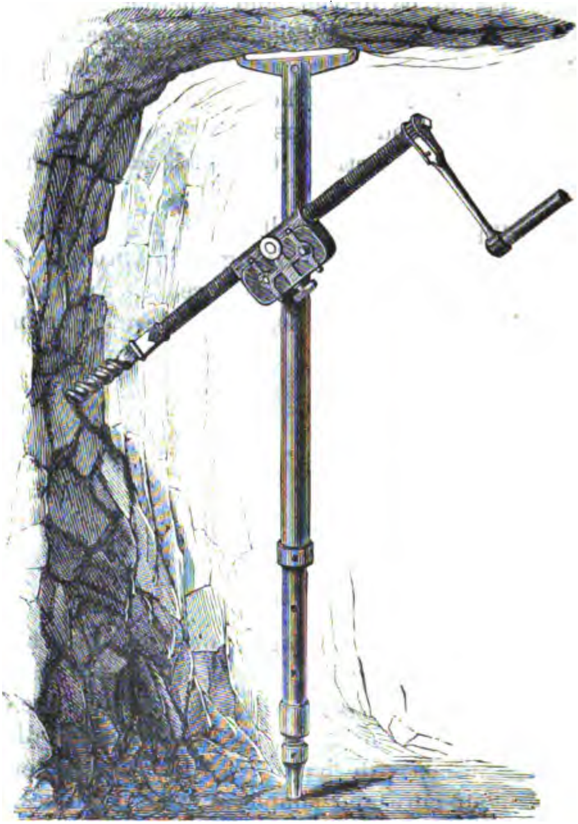


Fig. 25.

for ripping down roof or forcing up floor, whether by powder or wedge, or in boring in advance for water. It will also be useful for making plug holes when sinking shafts, termed by sinkers "plugging the ring or crib."

201. Give a short explanation of the fixing and setting of the perforator.

It is fixed and made secure, ready for boring, by placing one end of the standard on the floor, and the other end against the roof, as seen in the illustration, the tightening being by the screw. The clip which secures the machine to the standard, allows it to be placed at any required angle. The feed or rate of penetration is regulated by the small handle actuating the mechanism within the box. After the drill has been bored to its full length, the pressure is taken off the screw, the screw is run back, the short drill taken out and a longer one fixed in its place. One man can carry the machine about, can fit it, unfit it and work it.

202. How would you arrange your shot-holes to give the best results in driving stone drifts?

Suppose the shot-holes, as seen at A B C, fig. 24, have been bored by the machine, the required number at the face charged, and the machine taken away, those shots marked A, nearest the floor (holing shots), intended to unkey the face, are fired first. It will be seen that in fig. 24 the floorings, sheads, or partings dip from the face, but where the strata rise from the face, as shown in fig. 26, the shots

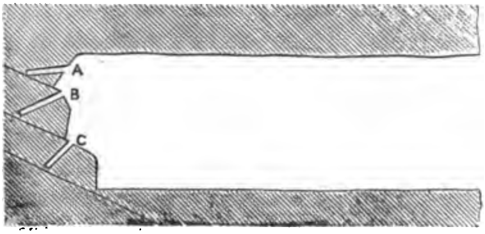


Fig. 26.

nearest the roof, marked A, should be fired first, then those marked B, so as to unkey or liberate those marked C nearest the floor.

203. What are the usual arrangements for removing and stowing the *débris* in stone drifts?

It is usual to have a set of men to remove the *débris*, while boring is going on and after shots are fired, either stowing it in some convenient place in the underground workings or sending it to surface. In some cases the material answers very well for brickmaking, and it is then sent to surface; otherwise it is trammed away and stowed in openings or thirlings on each side of the main roadways. If, however, no openings are available, then excavations, called dirt-holes, are made in the coal on the lower or dip-side of the roadways for its reception. For these, the coal is usually taken out the full thickness of the seam, and the holes driven in ten or fifteen yards, commencing with a width of 9 ft. and widened out at the lower end to 15 ft. or 20 ft., according to the nature or strength of the roof. When coal is worked on the longwall system, the *débris* can be utilised in the working places to build packs to support the roof at the working face.

204. Explain the method of lining and supporting the roofs and sides of stone-drifts.

When a stone-drift is driven to its required length, unless through hard rock, it is necessary to line or support the sides and roof. There are two methods in general use —one consists of timber arranged in various ways, and fixed at intervals where found to be requisite; the other method is by building a brick arch; the latter is preferable, especially if the drift has to remain open a great length of time, for two reasons—viz. (1) the support must be capable of withstanding a very severe strain; (2) the arching has a tendency to shield the roof and sides from the action of the atmosphere. As before mentioned, the thickness or strength of the arching should vary according to the strength and character of the strata.

205. What is the usual cost per yard of brick arching in stone drifts?

The work is generally performed and let to contractors at so much per lineal yard, the prices varying according to the diameter of the arch and thickness of brickwork; for an arch 8 ft. diameter, and brickwork 9 in. thick, the price per lineal yard would be 12s. The price increases or decreases with the diameter of the arch, 1s. 6d. for every foot; thus, with a diameter of 10 ft. and 9 in. work, the price per lineal yard would be 15s., or, observe the following rule:—Let D denote diameter of arch in feet, and L length of arch in yards, then to calculate the cost of 100 yards of arching 10 ft. in diameter, 9 in. thick, proceed thus:—

$$\frac{D \times 18 \times L}{240} = £75, \text{ then } \frac{10 \times 18 \times 100}{240} = £75.$$

With brickwork 14 in. in thickness, the price will be increased to 2s. for every foot the arch is in diameter; or, £1 for every yard in length. The contractors to find their own labourers, the brickwork to be set in mortar and the open spaces between the rock and arching to be packed up very tightly with fine *débris*. All material, however, to be placed near at hand.

206. What materials would you use for mortar-making or mixing for underground brickwork?

That depends very much upon the character of the place where the mortar is to be used. If the strata are dry, then the mixture should consist of one of new lime to three of sharp sand; or one of lime to two of sand and one of fine engine ashes or mine hess; but if the strata is of a wet or moist nature, then one of lime to two of sand and half cement. If a great quantity of water is given off from the strata, great density is required, and cement should be used without mortar.

207. If you have two shafts sunk to a seam of coal, dipping 1 in 5, and the seam has been dislodged by a fault between the two shafts, how would you connect the shafts?

As before pointed out, seams of coal are divided in various ways and directions by faults, &c., and to recover the seams, stone-drifts must be driven through the faults. Fig. 27 is a good illustration; two shafts are sunk to two seams, the seams have been dislodged or severed by a large fault requiring stone-drifts or tunnels to connect them for ventilation, &c. The difficulty of the work in this case appears rather formidable; the rise or dip of the seam one in five requires the tunnels to be driven rising or dipping one in three or more in order to win the coal again. If the tunnels are driven from No. 1 pit, the cost per yard will be greater than if from No. 2 pit, both for driving, removing the *débris* and keeping the water clear from the face; on the other hand, if driven from No. 2 pit the ventilation will prove an obstacle, as any air sent in will then have to be forced up bank by some mechanical power.

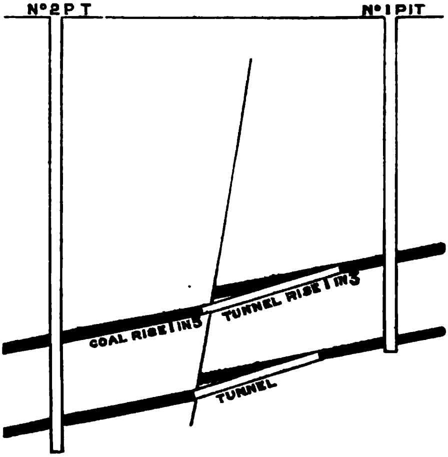


Fig. 27.

208. What are the different methods of ventilating stone drifts?

The ventilation of stone drifts may be accomplished in various ways—generally, however, by bratticing or air-pipes. The latter the author strongly condemns in coalmines except in cases of extreme emergency. The bratticing may consist of wood, canvas or brickwork. If the seam of coal when struck is likely to give off much gas, brickwork will be found preferable and most serviceable, as the ventilation can be better maintained, the brickwork being made perfectly tight between the roof and floor. The only extra cost incurred will be the cost of labour in erecting, for when the stone-drift is completed, the wall can be taken down and the bricks utilised for the building of stoppings in the openings or cross-cuts in the main roadways or coal levels. Brick bratticing is usually fixed in the middle of the drift, or nearly so, as shown in two tunnels, fig. 28, and

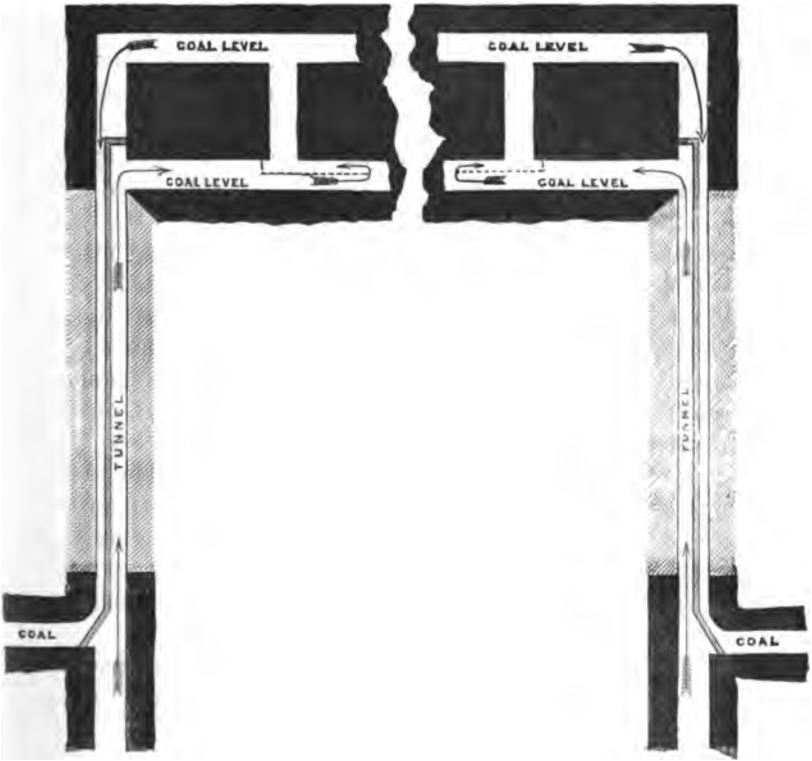


Fig. 28.

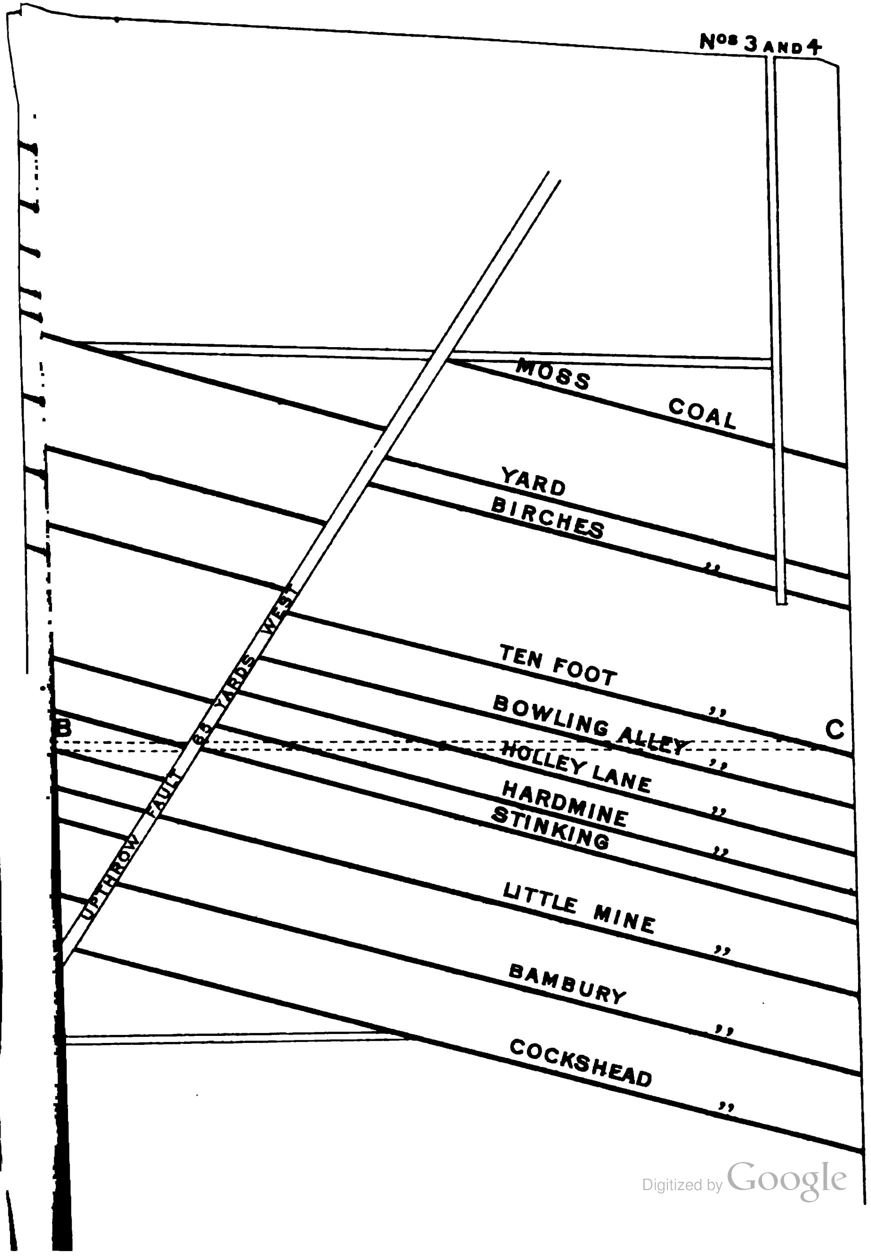
it allows a good distance to be driven in the seam of coal when struck, if required, so as to connect the drift with other workings or another drift.

209. What are the usual prices paid for stone-drifts, with Macdermott's perforator?

It is impossible to give definite figures or a rule as to the cost of tunnel-driving, the ground and other conditions varying so much. But, as an illustration, two tunnels were recently driven by Macdermott's machine at the Aldridge Colliery. These tunnels were driven on the slant at a dip of one in five from the yard coal to the deep coal, to connect the two seams, which are about 40 yards apart. The main tunnel was driven 7 ft. wide and 6 ft. high, and the counter air tunnel was 6 ft. wide and 5 ft. 6 in. high, the strata passed through consisting of strong metal and rock. For the main tunnel the price paid was £1 8s. per lineal yard, and for the counter tunnel £1 3s. per lineal yard. For these prices the contractors had to remove and convey the *débris* from the tunnel to the pit-eye, a distance of about 60 yards from the entrance of the tunnel, put in all timber (it being compulsory under the contract to put in settings every 3 ft.), to lay down all tram rails, to do all necessary work for ventilation, &c., and to provide their own powder, fuze, candles, &c. The author has no hesitation in saying that this work could not have been performed at anything like these prices by manual labour.

210. Can you give another case where the perforator has superseded hand-labour in tunnel-driving, under your management?

Yes; I could give many. Fig. 29 is the section of a colliery recently under the author's charge. A tunnel was required to be driven along the line A B C to win a number of seams of coal at intervals. Two tunnels were commenced at A, the main tunnel being 7 ft. wide and 5 ft. 6 in. high, and the price paid for driving was £1 2s. 6d. per lineal yard; the counter air tunnel was 5 ft. square, the


Nos 3 AND 4
MOSS COAL
YARD
BIRCHES ,,
TEN FOOT ,,
BOWLING ALLEY ,,
HOLLEY LANE ,,
HARDMINE
STINKING ,,
LITTLE MINE ,,
BAMBURY ,,
COCKSHEAD ,,
B
C
UPTHROW FAULT 65 YARDS WEST

price paid being 18s. per lineal yard. At these prices the contractors had to remove and convey the *débris* to the pit-eye, to put in all necessary timber and all appliances required for ventilation, &c. In this case also, had the work been performed by manual labour, it would have cost at least double the amount actually paid.

211. Can you mention a case where the perforator has been advantageously used in boring long holes to facilitate the connection of two points for ventilating purposes?

Yes; the author successfully completed, with the perforator, a borehole 9 yards in length, under the following conditions. A small staple pit was required in the underground workings to connect two airways. Had it been sunk downwards, being a great distance from the winding pit eye, considerable expense would have been incurred in conveying and raising the *débris* to the surface, but by making the pit upwards this expense could be saved, as the *débris* could be conveniently stowed away underground. But an obstacle presented itself—namely, insufficient ventilation to carry away powder smoke, &c. To overcome this difficulty two boreholes were put up in the exact place where it was intended to make the staple pit. Each hole was bored 1½ in. diameter, and afterwards rhymered out to 3 in. diameter. Being 3 ft. apart in very hard rock, sufficient ventilation was secured while the staple pit was made upwards, and the workmen also took advantage of the boreholes for blasting purposes.

212. Have you ever advantageously used the perforator in boring long holes to tap or drain off water in old workings?

Yes; at a colliery recently under the author's charge, we were approaching old workings containing water, and instead of having three boreholes in each heading, as required by the Coal Mines Regulation Act when approaching old workings likely to contain water, it was decided to bore one long hole with the perforator. The borehole was commenced 3 in. in diameter, and reduced in progression to 2 in. by using drills of a smaller gauge; the hole had an upward inclination of one in five, that being the angle of the seam, and when bored through 15 yards the water was tapped. The whole time occupied in boring the hole was about five hours.

213. Give a description of the boring-rods used in boring the foregoing holes.

The rods were similar to ordinary boring-rods made of ¾ in. round iron, in 3 ft. lengths, and screwed at each end like common gas-piping, and connected in like manner by screw boxes. There were also two short rods, each about 18 in. long, one with a socket at one end for the boring drill, and a screw similar to the other rods at the other end; the second short rod was made taper at its one end to fit into the socket of the driving screw of the perforator. A set of rods similar to the above to bore holes any required length can be made by an ordinary blacksmith.

CHAPTER V.

METEOROLOGY.

214. What is understood by meteorology?

Meteorology treats of atmospheric phenomena relating to weather and climate.

215. Can you state by whom and when the first observations on meteorology were recorded?

Exact observations began to be made on the pressure of the atmosphere when Torricelli invented the barometer—in 1643; on the temperature of the air when Fahrenheit invented the mercurial thermometer—in 1714; on the dryness of the air when De Saussure invented the hygrometer. These instruments have enabled observers to gather a large body of facts, which the labours of physicists enable us to use in the determination of the laws of meteorology. Hadley, in 1735, propounded a theory of the trade winds, and Dalton, in 1793, published acute explanations, grounded on the laws of physics, of the phenomena of wind, rain, clouds, &c., in relation to the temperature of the air.

216. What is a barometer? Give a short description of it.

A barometer is a straight glass tube filled with dry mercury, closed at one end, with the open end placed in a basin containing mercury.

217. Of what service is the barometer?

It measures, in fractions of an inch or other national standard scale, the pressure of the atmosphere.

218. What is the use of the thermometer?

The thermometer consists of a glass tube filled with mercury; it is used to measure the temperature of air, and to indicate the expansion of gases by heat.

219. What scales are adopted in graduating thermometers?

There are three: Fahrenheit, Centigrade, and Reaumur.

220. Describe the graduation of Fahrenheit.

The Fahrenheit thermometer is divided into 180 equal parts, called degrees. Fahrenheit did not, however, commence his scale at the freezing point. Erroneously thinking that he had obtained the greatest possible degree of cold by making a mixture of snow and salt, the temperature of which he found to be 32 of his degrees below the freezing point of water, he called the freezing point 32 degs.

221. Describe the Centigrade thermometer and its graduation.

The Centigrade scale—the space between two points, called respectively the freezing and boiling points—is divided into 100 equal parts, each of which is called a degree. The zero of the scale is placed at the freezing point, so that the boiling point is 100 degs. Centigrade.

222. Describe the graduation of Reaumur's thermometer.

Reaumur's scale (used in Russia and Sweden) resembles the Centigrade scale, except that the space between the freezing and boiling points is divided into 80 equal parts, so that water boils at 80 degs. Reaumur.

223. How are the relations between the three thermometers expressed?

The relations between the degrees of the three thermometers are expressed by the numbers 9, 5, 4. In converting from degrees Fahrenheit to Centigrade or Reaumur, we must remember first to subtract 32 and then reduce; whilst when passing from degrees Centigrade and Reaumur to Fahrenheit we must add 32 after the multiplication and division are completed.

224. If the Fahrenheit thermometer registers 100 degs., what would the Reaumur and Centigrade scales show ?

This is a sum in proportion, which is as follows:—180 degs. : 80 degs. : : 68 degs. (as 32 subtracted from 100 leaves 68); then, by rule $\frac{80 \times 68}{180} = 30 \cdot 2$ degs. + Reaumur. $\frac{100 + 68}{180} = 37 \cdot 7$ degs. + Centigrade. Thus, 100 degs. Fahr. would be 30·2 degs. Reaum. and 37·7 degs. Cent.

225. What is a hygrometer ?

The use of the hygrometer in mining is to ascertain the amount of vapour contained in the atmosphere in the return airways; the instrument usually containing the greatest quantity of vapour that can exist in it at its temperature.

226. Can you say why meteorologists in the United States can forewarn us in England of the approach of storms ?

Observations show that in the north temperate zone storms nearly always move eastward. Thus, in the United States, a storm may be preceded in its march by the telegraph; and knowing the velocity at which it is travelling, the ports on the eastern coast can get timely warning of its approach. This system of warning is inapplicable to the west coast of Europe.

227. Can you tell, from observations of the sky, when stormy weather may be expected ?

When it is moist and warm, and the sky is clear down to the horizon, or is streaked with cirrus and then covered with rain-clouds, we may expect stormy weather.

228. Under what circumstances would you expect the break-up of a frost ?

One of the surest signs of the breaking-up of frost is the setting in of the north-east wind, accompanied by a falling barometer and a greenish or yellow-greenish sky, and particularly if the wind veers from north-east to north and north-west.

229. How is it that air saturated with moisture weighs less than air in a dry state, knowing at the same time that the specific gravity of water is far beyond that of air?

Because of the extreme tenuity of watery vapours, the density of which is less than that of atmospheric air. Water is about 814 times the weight of air, but dry air is nearly twice the weight of vapour of water.

230. Is it possible to have rain with a rising barometer? If so, why?

Yes; a fall of rain with a rising barometer is not inconsistent, since with a fall of temperature the air becomes less rarefied, causing the barometer to rise. The same cause tends to condense the vapour in the air, and if the air be then nearly saturated, rain may fall.

231. How is it we have rain with a north-east wind, and a rising barometer?

Because the wind has come over the Arctic Ocean, and derives moisture from the ice and snow over which it has blown; it mingles with and cools or condenses the vapour contained in the air of our latitude, which then falls in cold and uncongealed rain on the earth.

232. To what extent does the barometer vary in its rise and fall?

The pressure or weight of atmospheric air varies very considerably in the different states of the weather; as the density of the air varies so also does the barometer vary in its rise and fall from 28½ in. to 31 in. of mercury column. This is from 2,016 lb. to 2,196 lb. per square foot on the earth's surface, or from 14 lb. to 15¼ lb. per square inch, or a difference of pressure of 180 lb. per square foot, whether on the surface or in the underground workings.

233. Give an illustration of the total reduction of pressure that would take place in an underground gallery by the barometer falling from 31 in. to 28½ in. of mercury column.

We will suppose, for illustration, that an underground gallery is 1,000 yards in length, and the perimeter of the same is 30 ft. or 9 ft. wide and 6 ft. high; the total reduction of pressure in this gallery, when the barometer falls from 31 in. to 28½ in., would be 1,000 × 3 = 3,000 ft. in length, 3,000 × 30 = 90,000 × 180 = 16,200,000 lb., total reduction of pressure. The reduction of atmospheric pressure, as shown by a barometer, is a warning that an increased quantity of gas may be expected to be given off, and therefore calls for increased care from those who are in charge of mines to keep up the ventilation at its greatest point, for the gases penned up in goaves and abandoned excavations will expand in volume proportionately to the reduction of pressure which causes the fall of the barometer.

234. Does the barometer on the pit bank give a true indication or foretell an increase of gas in the underground workings?

Experiments and observations I made at the Mossfield Colliery, Longton, in the year 1883, proved beyond doubt that the barometer on the surface cannot be relied upon to indicate an approaching increase of gas in the underground workings. My observations were made conjointly with similar observations made by Mr. W. Fairley, Ph.D., and other mining engineers in different parts of England. (A copy of my observations is given as an appendix to this chapter.)

235. Do you consider the official colliery warnings, published from time to time in the newspapers, of any practical service?

No; I consider them worthless and misleading. As I have said before, the barometer at the surface is not to be relied upon as an indicator of gas in the underground workings, and if this is so with the instrument upon the spot, much less should reliance be placed upon readings which must necessarily have been made many hours before the warnings are published. The movements of the gases themselves are likely to be much more rapid than those of the mercury. The warnings have been strongly condemned by many of the leading mining engineers. At a meeting of the Manchester Geological Society, Mr. Dickinson, her

Majesty's Chief Inspector of Mines, said it was really very difficult to trace any connection between explosions and the pressure of the barometer. They had these colliery warnings issued through the newspapers at frequent intervals, in which they were cautioned at certain periods to use extra care. He was not sure whether these spasmodic efforts were not doing more harm than good. It required constant care in the pits, and the utmost care at all times; but using extra care for the next two or three days, as it said in the newspapers that morning, meant that less care might be taken in several days after. There ought to be no laxity at any time in the management of a mine. Mr. Miles Settle said his experience of these colliery warnings was, that whilst they tended to upset the men's minds they were of no practical service. The danger had come before they got these warnings; many a time they were down in the pit before they knew anything about these warnings. With regard to the effect of barometrical changes, he had found that they had more gas given off with either a rising or a falling barometer than with an ordinary standing barometer. Mr. S. Garside thought it was a sad mistake to put these warnings into the newspapers. In a colliery they had always to be using all the care they possibly could. And in the final report of the Royal Commission on Accidents in Mines, the Commissioners say:—"While we recognise that variations of atmospheric pressure exert an influence on the escape of gases which have accumulated in cavities, and possibly to a slight extent on that of gases emitted directly from the coal, we entertain great doubt as to the wisdom of placing reliance on the issue of meteorological warnings. These can at best only convey very imperfect information, which, moreover, may be sometimes dangerously misleading. We are of opinion that safety would be much more likely to be ensured by unceasing vigilance on the part of the officials and workmen in the mine than by any attention to such warnings."

236. Does an increase or decrease of pressure of the atmosphere affect the volume of air passing through a mine?

Increase or decrease of pressure of the atmosphere has little or no effect in altering the volume of air passing through a mine in a given time, although it alters the weight of such air, as above stated, to a considerable extent.

237. How can you ascertain by the barometer the pressure of the atmosphere on the earth's surface per square inch and per square foot?

The pressure per square inch is found by multiplying the height of the barometer by ·4908—the weight of a cubic inch of mercury—and this again by 144, to find the pressure per square foot; or we will suppose the barometer to be 30 in. on the barometric scale, thus, 30 × ·4908 = 14·72 lb., and per square foot 14·72 × 144 = 2,120¼ lb.

238. Explain the use of the thermometer in mines.

It is principally used for ascertaining the difference of temperature in downcast and upcast shafts, and the variation and action of temperature upon the ventilation by reducing or adding to the weight of the air.

239. Will the barometer indicate the friction of air in mines?

Yes; the barometer shows this by the reduction of pressure between the intake and return, which is the measure of the power spent on the friction, but the water-gauge is more commonly used.

240. Describe how the weight of a cubic foot of air can be ascertained by the use of the barometer and thermometer.

Let H equal height of barometer, T equal height of thermometer, and W weight of cubic foot of air:—

$$W = \frac{1{\cdot}3253 \times H}{459 + T}$$

241. What are the common indications of coming change of weather?

The following guides in predicting weather-changes are selected from the *Barometer Manual* of the London Board of Trade:—

(1.) If the mercury, standing at 30 in., rise gradually while the thermometer falls, and dampness become less, N.W., N. or N.E. wind; less wind or less snow and rain may be expected.

(2.) If a fall take place with a rising thermometer and increasing dampness, wind and rain may be expected from S.E., S. or S.W. A fall in winter, with a low thermometer, foretells snow.

(3.) An impending north wind, before which the barometer often rises, may be accompanied with rain, hail or snow, and so forms an apparent exception to the above rules, for the barometer always rises with a north wind.

(4.) The barometer being at 29½ in., a rise foretells less wind or a change of it northward, or less wet. But if, at 29 in., a fast first rise precedes strong winds or squalls from N.W., N. or N.E., after which a gradual rise with falling thermometer, a S. or S.W. wind will follow, especially if the rise of the barometer has been sudden.

(5.) A rapid barometric rise indicates unsettled and a rapid fall stormy weather with rain or snow; while a steady barometer, with dryness, indicates continued fine weather.

(6.) The greatest barometric depressions indicate gales from S.E., S. or S.W.; the greatest elevations foretell wind from N.W., N. or N.E., or calm weather.

(7.) A sudden fall of the barometer, with a westerly wind, is sometimes followed with a violent storm from the N.W., N. or N.E.

(8.) If the wind veer to the south during a gale from the E. to S.E., the barometer will continue to fall until the wind is near a marked change, when a lull may occur. The gale may afterwards be renewed, perhaps suddenly and violently; and if the wind then veer to the N.W., N. or N.E., the barometer will rise and the thermometer fall.

(9.) The maximum height of the barometer occurs during a north-east wind, and the minimum during one from the south-west; hence these points may be considered the poles of the wind. The range between these two heights depends on the direction of the wind, which causes on an average, a change of half-an-inch; on the moisture of the air, which produces, in extreme cases, a change of half-an-inch; and on the strength of the wind, which may influence the barometer to the extent of 2 in. These causes, separately or conjointly with the temperature, produce either steady or rapid barometric variations, according to their force.

242. Can you give any conclusions deduced from your own observations?

For a number of years I have given a great deal of study to the barometer and thermometer, and to the various changes of the atmosphere; and have kept a daily diary of the same. The following are some of the changes I have noticed in recording barometrical indications, observing that more attention should be paid to the tendency of the mercury at the time of observation, whether it stands high or low. The following are rules of barometric reading which I have found generally accurate, though, of course, liable to exceptions:—Fair weather is indicated as a rule by the rise of the mercury; foul weather by the fall of the mercury; thunder is indicated by the fall of the mercury in sultry weather; cold is indicated by the rise of the mercury in spring, autumn and winter; heat by the fall of the mercury in summer and autumn; frost is indicated by the rise of the mercury in winter; thaw by the fall of the mercury during a frost. Continued bad weather is probable when the fall of the mercury has been gradual through several fine days; continued fine weather when the rise of the mercury has been gradual through several foul days; bad weather of short duration when it sets in quickly; changeable weather when an extreme change has suddenly set in; wind is indicated by a rapid rise or fall unattended by a change of temperature; the mercury rising and the air becoming cooler promises fine weather; but the mercury rising and the air becoming warmer, the weather will be changeable. If the top of the column of mercury appears convex or curved upwards, it is an additional proof that the mercury is rising, and that we may expect fine weather; but if the top of the mercury is concave or curved downwards it is an additional proof that the mercury is falling, and we may expect bad weather.

[For tables and a detailed account of the use of meteorological instruments generally, see Mr. Buchan's *Handy Book of Meteorology.*]

243. Can you give the underground temperature of a few of the deepest mines in Great Britain?

Yes; the following is from a report presented to the British Association by a committee on underground temperature. Observations had been taken at the East Manchester coalfield, the Talavgoch Lead Mine, Flintshire, and at the Radstock Collieries, Bath. With respect to the observations in the East Manchester coalfield, these were taken respectively at Ashton Moss, Bredbury, and Nook Pit. At Ashton Moss, at a depth of 2,790 ft., the temperature was 85·3 degs.; at Bredbury Colliery, at a depth of 1,020 ft., the temperature was 62 degs.; and at Nook Pit, a depth of 1,050 ft., 63½ degs. These observations agreed exceedingly well. The mean natural temperature might be assumed to be 49 ft. The increments of temperature at that depth would then stand as follows:—Ashton Moss, 36·3 degs. in 2,790 ft.; Bredbury, 13 degs. in 1,020 ft.; Nook Pit, 13⅓ degs. in 1,050 ft. This gave, for each degree of increase—Ashton Moss, 76·9 ft.; Bredbury, 78·5 ft.; Nook Pit, 79 ft. the pressure, and dividing by 33,000. The resistance is according to the length of the air channel for the same. In Flintshire the observations showed great irregularity. Taken at a place in a lead mine 660 ft. deep, the temperature was 62 degs. Fahr., which, 48 degs. being assumed to be the surface temperature, gave an increase of 14 degs. in 660 ft. or of 1 deg. for 47 ft. At the Radstock Colliery, observations were made at three pits—the Wells May Pit, 560 ft. deep; the Ludlow Pit, 1,000 ft.; and the third in the same pit, at a depth of 810 ft. Assuming 50 degs. in that locality as surface heat, for 560 ft. the increase was 11·7 degs.; for 810 ft. 13 degs.; and the same for 1,000 ft. Professor Everett, who presented the report, remarked that as they went into the earth they found it gradually hotter, varying from 1 deg. in 30 ft. or 40 ft. in some parts to 1 deg. in 100 ft. in others.

APPENDIX TO CHAPTER V.

A RECORD OF BAROMETRICAL AND THERMOMETRICAL OBSERVATIONS MADE AT MOSSFIELDS COLLIERY, LONGTON, IN 1883.

The following is a copy of my observations which were published in the *Coal and Iron Trades Review* of January 30, 1885.

In making these observations, which extended over four months, I placed one barometer on the pit bank and another in the underground workings, at a depth of 437 yards from surface, the top of the pit shaft being about 603 ft. above sea level. I took the records twice daily, viz., at 7 a.m. and 3 p.m., or as near that time as circumstances would allow.

The tables show the barometrical, thermometrical, &c., records for the weeks ending September 15 and September 22, in the year 1883.

A RECORD OF BAROMETRICAL AND THERMOMETRICAL READINGS MADE AT MOSSFIELDS COLLIERY, LONGTON.

Downcast Pit, Diameter, 10 ft. 6 in.; Depth, 437 yards.
Upcast Pit, Diameter, 10 ft. 6 in.; Depth, 437 yards.

1883. Date. September	Weather.	Wind.	At top of shaft, 603 ft. above sea level.		Underground distance from shaft, 322 yds. Above shaft bottom, 80 ft.		Quantity of air passing near instruments underground.	Time.		GENERAL REMARKS.
			Barometer.	Thermometer.	Barometer.	Thermometer.		Surface.	Underground.	
Mon. 10	Very wet	S.E.	29·26	54	30·58	59	2,875	7.30 a.m.	7.45 a.m.	Gas fired in lamp 3 yards off feeders.
Mon. 10	Very wet	S.E.	29·24	59	30·56	59	2,900	3.0 p.m.	3.15 p.m.	Gas fired in lamp 3¼ yards off feeders.
Tues. 11	Dullish	N.W.	29·42	51	30·80	60	3,000	7.15 a.m.	7.30 a.m.	Gas fired in lamp 3 yards off feeders.
Tues. 11	Fine	N.W.	29·50	58	30·89	60	2,750	3.0 p.m.	3.15 p.m.	Gas fired in lamp 2 yards off feeders.
Wed. 12	Foggy	N.W.	29·57	52	30·95	60	2,900	7.15 a.m.	7.30 a.m.	Only a little gas given off at feeders.
Wed. 12	Fine	E.	29·57	61	30·97	61	3,000	3.0 p.m.	3.15 p.m.	Slight show of gas at feeders.
Thu. 13	Foggy	N.W.	29·62	53	31·00	60	3,000	7.30 a.m.	7.45 a.m.	Slight show of gas at feeders.
Thu. 13	Very fine	S.W.	29·62	60	30·92	61	2,750	3.0 p.m.	3.15 p.m.	Slight show of gas in lamp at feeders.
Fri. 14	Very foggy	E.	29·54	53	30·91	60	2,900	7.15 a.m.	7.30 a.m.	Increase of gas at feeders.
Fri. 14	Very fine	S.E.	29·47	61	30·80	61	2,875	3.0 p.m.	3.15 p.m.	Still more gas given off at feeders.
Sat. 15	Dull & wet	S.W.	29·35	53	30·70	60	Extra air put on 3,000	7.0 a.m.	7.15 a.m.	Extra gas fired in lamp 3 yards off feeders.
Sat. 15	Dull & wet	S.W.	29·25	62	30·70	62	2,695	3.15 p.m.	3.28 p.m.	Gas fired in lamp 4 yards off feeders.
Mon. 17	Very fine	S.E.	29·54	57	30·90	61	2,500	7.15 a.m.	7.30 a.m.	Show of gas in lamp at feeders.
Mon. 17	Very fine	S.E.	29·56	67	30·92	61	2,875	3.15 p.m.	3.30 p.m.	Slight decrease of gas.
Tues. 18	Very fine	S.E.	29·55	60	30·89	61	2,750	7.15 a.m.	7.30 a.m.	Slight increase of gas.
Tues. 18	Very fine	S.	29·54	66	30·87	62	2,875	3.0 p.m.	3.15 p.m.	Slight increase of gas given off since morning.
Wed. 19	Very foggy	S.E.	29·51	58	30·83	61	3,000	7.5 a.m.	7.20 a.m.	Gas fired in lamp 2 yards off feeders.
Wed. 19	Fine	S.E.	29·40	65	30·72	62	2,900	3.15 p.m.	3.30 p.m.	Gas fired in lamp 3 yards off feeders.
Thu. 20	Dullish	E.	29·18	58	30·47	62	3,000	7.15 a.m.	7.30 a.m.	Gas fired in lamp 3¼ yards off feeders.
Thu. 20	Wet		29·14	58	30·43	60	2,875	3.25 p.m.	3.35 p.m.	Extra gas fired 4 yards off feeders.
Fri. 21	Foggy	E.	29·12	54	30·40	62	2,900	7.0 a.m.	7.15 a.m.	Gas fired in lamp 3¾ yards off feeders.
Fri. 21	Fine	N.W.	29·15	60	30·49	62	2,875	3.0 p.m.	3.15 p.m.	Gas fired in lamp 3¼ yards off feeders.
Sat. 22	Dull	S.E.	29·10	55	30·45	60	3,000	6.50 a.m.	7.5 a.m.	Gas fired in lamp 3¼ yards off feeders.
Sat. 22	Very dull	N.W.	29·20	60	30·55	63	2,900	2.50 p.m.	3.5 p.m.	Gas fired in lamp 2 yards off feeders.

WILLIAM WARDLE, Manager.

A Record of Barometrical and Thermometrical Readings made at the Mossfields Collieries, Longton, by W. Wardle.—Variation or Difference from each Previous Reading.

1883.	Surface.				Underground.				General Remarks.
Date.	Bar.		Ther.		Bar.		Ther.		
Sept.	+	—	+	—	+	—	+	—	
10	—	·02	5	—	—	·02	=	=	Increase of gas at feeders.
11	·18	—	7	8	·24	—	1	—	Decrease ,, ,,
11	·08	—	7	—	·09	—	=	=	,, ,, ,,
12	·07	—	—	6	·06	—	=	=	,, ,, ,,
12	=	=	9	—	·02	—	1	—	,, ,, ,,
18	·05	—	—	8	·03	—	—	1	,, ,, ,,
13	=	=	7	—	—	·08	1	—	Increase ,, ,,
14	—	·08	—	7	—	·01	—	1	,, ,, ,,
14	—	·07	8	—	—	·11	1	—	,, ,, ,,
15	—	·12	—	8	—	·10	—	1	Extra increase ,,
15	—	·10	9	—	=	=	2	—	Increase ,, ,,
17	·02	—	10	—	·02	—	=	=	Decrease ,, ,,
18	—	·01	—	7	—	·03	=	=	Increase ,, ,,
18	—	·01	6	—	—	·02	1	—	,, ,, ,,
19	—	·03	—	8	—	·04	—	1	,, ,, ,,
19	—	·11	7	—	—	·11	1	—	,, ,, ,,
20	—	·22	—	7	—	·25	=	=	,, ,, ,,
20	—	·04	=	=	—	·04	—	2	,, ,, ,,
21	—	·02	—	4	—	·03	2	—	Decrease ,, ,,
21	·03	—	6	—	·09	—	=	=	,, ,, ,,
22	—	·05	—	5	—	·04	—	2	,, ,, ,,
22	·10	—	5	—	·10	—	3	—	,, ,, ,,

My conclusions from these observations are that a barometer placed on the pit bank is not to be relied upon as a true indicator to forewarn the approach of an increase of gas in the underground workings. In all the observations at the Mossfields Collieries, I noticed that the barometer placed in the underground workings was much more sensitive to an increase or decrease in the atmospheric pressure than that placed at the surface; that is to say, the barometer underground denoted changes of pressure much earlier than the one at surface. I also noticed that the gas made its presence felt long before either of the barometers showed any signs of falling.

A rising barometer should always be considered an indication of an increase of gas and danger; and an unusually high barometer is always an intimation of "present" danger. These facts prove that the period of greatest danger is that when the barometric column is high or rising, although gas undoubtedly appears in greater quantities in the underground workings when there is a decrease of the atmospheric pressure. The officials and men being conversant with the fact that more gas appears with a decreasing mercury column, should not relax their precautions against their unseen enemy when the mercury begins to rise.

It has long been admitted that additional care should be exercised during a decreasing barometric pressure. This being true, it is much more important that the additional care which is admittedly exercised with decreasing mercury column should not in the least degree be relaxed when the mercury is rising. While the mercury is rising, the whole of the gas which has escaped during its fall, and which, probably, has accumulated in every available space, should be driven out of the underground workings, and when there is an unusually high barometric column it is most desirable that special search should be made for this accumulated gas, with a view to removing the same; then the only gas to be dealt with when the mercury column falls would be that escaping from the coal. I wish it here to be understood that when there is an unusually high barometric column this is an intimation of "present" danger. I am not advising the officials and men to relax their precautions when there is an usually low barometric column, as gas undoubtedly appears in greater quantities when there is a decreasing mercury column, especially if the decrease has been going on over several days. When this is the case, the general cause of explosions is that the whole of the return airways become charged with gas, the most violent forces of the explosion being generally felt in the return airways, but when an explosion takes place with a high mercury column, the most violent forces of the explosion are generally felt at or near the working face, showing that the gas has been ignited as soon as it has escaped from the coal or gob.

In the year 1883 we had a larger number of explosions with a low than a high mercury column, but these explosions took place when we had had an unusually low mercury column for several days.

For instance, we will take two explosions—viz., one at the Big Pit, Hanley, North Staffordshire, and the other at the Accrington Colliery, Lancashire. The Big Pit explosion took place on Sunday, the 2nd of September, 1883, and for several days before this explosion the barometer had been unusually low, and on the morning of the explosion the column was down to 27·90 in. The gas was supposed to have fired at the ventilating furnace. The explosion at the Accrington Colliery took place on Wednesday, the 7th of November, 1883, at 8.50 a.m., and resulted in the loss of sixty-six lives. In this case also the barometer had been unusually low for several days before, and a large quantity of gas had been given off from a blower in the mine. But, on the other hand, as I have said, a large percentage of explosions have generally occurred at semi-annual periods, and generally with a high barometric pressure. For instance, we will take two—viz., the one at the Oaks Colliery, Yorkshire, and that at the Talk-o'-th'-Hill Colliery, North Staffordshire, which took place on December 12 and 13, 1866, by which 362 and 92 lives were lost respectively.*

It seems probable that, if a closer differentiation could be made, it would be found that many of the explosions occurring during a high barometric pressure have some connection with local or general storms; that is to say, at such a time when an unusually high barometric column exists, a sudden fall in the atmospheric pressure, or a sudden disturbance of the atmosphere, presaging a local or general storm, would surely be accompanied with an increased outflow of gas, which would readily become explosive at the working face, while the air would still remain safe in the return airways, the gas at the working face being much more sensitive to denote changes than the barometer. Storms nearly always move eastward or south-eastward. For years I have noticed that greater quantities of gas are given off in the underground workings when the wind comes from the west or from a south-westerly direction. The wind was in this direction on the day of the Accrington explosion, and also on the day of the Big Pit explosion, and had been in this direction for several days before the latter occurred.

The two maximum periods at which storms do occur, June and December (in Great Britain), seem to indicate that these disturbances exercise an important influence on the relative efflux of gas. This is my impression, and the results of my observation go to strengthen it. By way of proving the soundness of my impression, as soon as I found the efflux of gas increasing at the blowers in the headings in which I had chosen to make the experiments, knowing at the same time that the wind was in the west or south-west, and also knowing that the barometer at the surface did not denote any change in diminished pressure, and to be sure that this increased emission of gas from the coal was not brought about by a reduced ventilation, we took the quantity of air in the heading at each observation. In several instances with a south-west wind we put on a larger quantity of air, and yet the increased emission of gas from the blowers in the coal could readily be observed, while the barometer at surface did not denote any change in diminished pressure for some time afterwards.

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* It was proved at these accidents that the barometer did not indicate the change of pressure until some time after the change had taken place.

Mr. J. Warburton, a well-known and able mining engineer of Yorkshire, in speaking of the barometer as an indicator of danger, considers that it is too slow for the purpose of detecting the presence of those influences that contribute to the charging of a mine with gas, seeing that the gas will be in the mine long before the mercury shows the fall. With respect to there being more explosions in winter than in summer, he considers that it is due to the absence of a high temperature in the winter as compared with the warmer portions of the year. This is shown by the difference in the temperature of mineral seams in the two periods of the year. In Yorkshire, for instance, we are told that the temperature of many of the seams of coal is 70 degs., and is so during both summer and winter. In July, when the air is taken into the downcast shaft at 70 degs., the temperature and the thermal forces are equal, and although there may be a sluggish ventilation as regards velocity, there is an energetic one in what may be called its prohibitive ability. On the other hand, in the winter the air taken from the surface into a mine may not be more than 34 degs. The result is that the ventilation is sharp and keen, and is felt by all persons underground. This is simply the cold aqueous vapour absorbing the heat of the bodies of the men, and in degree it does the same with the coal that remains at its temperature of 70 degs., the gases and vapours from the mineral being as active in radiation as the cold vapour is in absorption. Consequently between the two powers, radiation and absorption, an amount of gas is given off that is difficult of calculation, and from this and this alone, it is inferred, arise the many severe explosions there are in the winter time. The changing nature of the condition of a mine is too often overlooked, undoubtedly, in connecting the atmosphere with explosions. As an illustration of this Mr. Warburton states that a "weight" may be coming on, and in its motion, press so heavily on the face of the coal as to squeeze or press out the gas from 2 or 3 ft. or even more from the solid mineral, and practically fill the pit with gas when only two hours before it was quite clear and free. The changing condition of the barometer would be an infinitesimal amount compared with the enormous amount of moving rock of varying thickness up to 40, 50, or even 100 yards, and it is by no means illogical to contend that many of the explosions that happen now with a falling roof may be due to this instead of the common conclusion that the gas comes down with the roof. This is all the more likely to be the case assuming that the goaf is free from gas. The writer pertinently asks how it is that more than 90 per cent. of the explosions take place in the intake, and that this admitted fact has not led to any investigation in that direction. This may be accounted for by the painful experience of those connected with mines that gas accumulates during the night. Yet the pits should be clearer in a morning when no work is going on; but they are not so. This, no doubt, is due to the low temperature of the air which is taken into the pit during the night as compared with the day. The lamps and the tools with which the men work, not moving about, the aqueous vapour can receive its requirements from the strata of the mine, and consequently absorbs more heat, probably in the form of gas, than it would if all were at work. In bringing this gas to an explosive point it must be taken into consideration that when the temperature is low the aqueous vapour occupies a much less space, and the atoms of oxygen are much nearer to each other, so that, space for space, under these conditions a less amount of gas will bring the mixture to an explosive point. Consequently, in the winter season there is a keener, quicker kind of gas, with a top on the flame that will fire before it is half the length it will show in warmer seasons and yet not explode, whilst it is well known that gas in winter is more severe in its burning effects than in summer. Or, in other words, the gas exploding in winter burns keener and deeper in the same space of time. Taking the air at 70 degs., as previously stated, it will be found by experience, we are informed, that the atoms of oxygen are further apart. Consequently, space for space, there are far fewer atoms of oxygen, so that if the gas comes off at all, which it will undoubtedly do by the pressure acting upon the coal and by cutting and getting it down, it requires a considerably larger quantity of gas to bring the atmosphere up to an explosive point, owing to the less amount of oxygen in the air—that is, considering space for space. This is what Mr. Warburton calls negative prohibitive ability. Hence it will be inferred that an explosion in winter, taking space for space, is far more intense than one in summer.

CHAPTER VI.

VENTILATION.

244. What is ventilation and what its use to the human system?

Man is so constituted that he is dependent on the materials with which he is surrounded for nourishment and support. Probably there is nothing more necessary to the health of the body than a pure atmosphere. The object of mine ventilation is to supply all underground workings with fresh air.

245. Why are fans, furnaces, &c., placed at collieries and by what are their sizes regulated?

They are required to supply the mines with fresh air. The quantity of air is dependent on the loss of oxygen from the atmosphere due to the breathing of men and animals, and the burning of lamps, &c., and on the vitiation of the atmosphere in the mine by the escape of noxious gases, powder-smoke, firedamp, carbonic acid, &c. As it is not possible to determine beforehand the quantity of firedamp that will be given off in a mine, it is impossible, as a rule, to determine the total quantity of air that a fiery mine will require. The size of fan or furnace must be judged with reference to local conditions and the larger or smaller quantities of firedamp that escape.

246. What is meant by natural ventilation?

Natural ventilation is a term applied in cases where a current of air passes through the underground workings without the aid of any mechanical appliance. It is an accepted fact, that as fast as a shaft is sunk the pressure of the surrounding atmosphere fills it with air, and when the sinking is completed, if a mine or road be driven in any direction or any distance, the same pressure will force air up to the face. If a second shaft be sunk from the same surface level and the bottoms are on the same level and connected, then from the natural heat of the mine the air will be put in circulation, and what is called natural ventilation will exist, the movement of air being in the direction of the weaker column. The weaker column will depend upon certain conditions, which are:—One shaft may be wetter than the other, which will necessarily become a downcast where no greater disturbing cause exists (from this cause a pumping shaft generally becomes a downcast); the relative depth of the two shafts; the relative diameter of the two shafts. From this it follows that the excess of force in one shaft above the other will be the measure of the moving power, and it will at once be seen that the greater the excess the greater will be the quantity of air set in circulation, other things being equal. This excess of power may be obtained by altering the density of either of the columns of air; either by compression in the downcast shaft, expansion in the upcast, or by pumping or exhausting by fan the air from the upcast.

247. Give a sketch illustrating natural ventilation, and say which shaft will be the upcast in the summer months, and which will be the upcast in the winter months, the tops of both shafts not being on the same level.

It is only during very cold weather that natural ventilation can be of any practical use. Fig. 30 is a sketch where the tops of the shaft are not on the same level, and if dependent upon natural ventilation the current of air would reverse with changes in the weather—that is, on a very hot day the deeper shaft would be the downcast, because the column of air in the shaft A B would be of the temperature of the strata, which on hot days is lower than the temperature of the atmosphere; and, therefore, it would be heavier than the column of air in the shaft and length above the shaft C D E, consequently the heavier column would press upon the lighter and displace it; this would give rise to a current; or, in other words, the weight and pressure principle mentioned in other questions would come into action. On cold days the shaft A B would be the upcast, because the temperature of this shaft would be of the temperature of the strata, which on cold days would be greater than the atmosphere, and therefore would be lighter than the column of air in the shaft and length above the shaft C D E; consequently the heavier column would displace the lighter and give rise to a current.

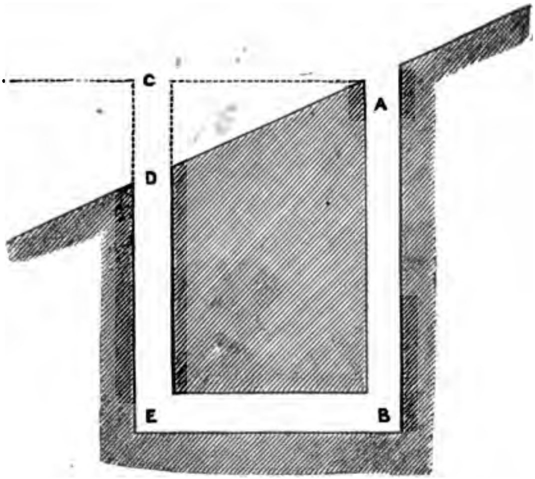


Fig. 30.

248. In two shafts of equal depth—that is, the tops of both shafts being on a level—and say 1,000 ft. deep, suppose on a cold day the average temperature of the air in the downcast is 25 degs., or 7 degs. below freezing point,

and the air in the upcast and mine, say, 65 degs., what will be the difference of water-gauge or pressure?

Under the above circumstances the difference of water-gauge or pressure would be found as follows:—

One cubic foot of air at 25 degs. weighs ·0821460 of a lb.
„ „ „ 65 degs. „ ·0758753 „

Difference of weight per foot is ·0062707 „

Example: $\cdot 0062707 \times 1{,}000 = \frac{6\cdot 2702}{5\cdot 2} = 1\cdot 20$ in. of water-gauge. The above is what might be expected on an extremely cold day in a mine where the underground workings are of a high temperature.

249. Suppose a shaft to be partitioned off into two compartments for ventilating purposes—one compartment having, say, an area of 100 square feet, and the other an area of only 16 square feet, why should Nature select the smaller compartment for the upcast?

As before stated, air is affected by heat—that is, a rise of temperature increases its volume if the pressure remains constant, consequently the air would be more rarefied at the bottom of the shaft than at the top, owing to the heat given off from the strata, &c.; the movement of the air would be in the direction of least resistance—viz., up the smaller compartment, the larger compartment becoming the downcast. This will be better understood by remembering that air, like other substances, is affected by gravity and therefore has weight, and because of its weight it must of necessity exercise pressure, this pressure in every direction being the same. Air, then, has weight, is elastic, can be compressed, and like other gasy bodies, expands under the influence of heat, and this expansion is in proportion to the amount of heat applied, or in proportion to the volume of air influenced by a given amount of heat. In our example the air in the smaller compartment would be more affected by the heat given off from the strata than the column of air in the larger compartment, and would thus become the upcast. Again, air having weight and being affected by gravity, it follows that the excess of pressure in the larger compartment would cause the air to move in the direction of the weaker column, and it will at once be seen that the greater the excess, the greater will be the quantity of air set in circulation, other things being equal. This weight and pressure theory has been borne out in practice, and will be further explained in other questions.

250. What power do you prefer for ventilation generally in mines—water-fall, steam-jet, fan or furnace—and why?

I prefer the fan. The furnace is not recommended, on account of the great number of accidents, underground fires and explosions, &c., that can be traced to its use. My objections to waterfall for ventilation are that the water has to be pumped to surface again, and that it damps the air and rots the timber. The steam jet does not give an adequate amount of ventilation for the fuel it consumes. The fan will put in circulation a greater quantity of air in proportion to the quantity of fuel consumed than the furnace for a shallow pit, and the ventilation may be considerably increased in cases of emergency by simply increasing the speed of the engine. Taking all things into consideration, I should prefer the fan.

251. What distance from the bottom of your shaft would you place a furnace to produce good results?

I have always found the furnace, placed at about 30 yards from the shaft, gives the best results, and the tunnel leading from the furnace to the shaft to rise about 4 in. per yard.

252. What precaution would you take, when putting in a furnace, against its taking fire and igniting the surrounding strata?

I would pack round the outer shell of brickwork well with sand—say, about 18 in. thick, and screen the sand through a fine riddle before putting it in, to keep out all combustible substances, such as small pieces of coal, wood, cotton waste, &c. Underneath the outer shell another shell of brickwork should be built, and each shell of arching carried to the upcast shaft; between these two shells an air-space of not less than 6 in. should be left all round, allowing the air to circulate through, so as to keep the upper shell cool. Underneath each firegrate I would place a wrought iron pan the full length and width of the grate itself and about 8 in. deep, so that 6 in. of water may be constantly kept in the pan by means of pipes from the bottom of the shaft, and all ashes and hot cinders dropping into the pan are immediately cooled.

253. What is a dumb drift and its use in ventilation?

A dumb drift is a tunnel or stone drift driven through the measures from a certain point in the return airway to the upcast shaft. It is usually driven at such an angle that it will come out in the shaft about 10 or 15 yards above the furnace drift, so that if there is any noxious gas in the return air, it does not come in contact with the flames of the furnace, all the return being generally arranged to pass through the dumb drift.

254. How do you calculate the horse-power of a furnace?

The power of a furnace is calculated by finding the difference between the weight of the air in the downcast and upcast shafts, which is called the motive column. The following is the rule for finding the weight of a cubic foot of air by the use of the barometer and thermometer, at any temperature and under any pressure:—Let H equal height of barometer, T equal height of thermometer, and W weight of a cubic foot of air:—$W = \frac{1 \cdot 3253 \times H}{459 + T}$. When the weight of a cubic foot of air has been found by this rule, the weight of a cubic foot of air in the downcast is then multiplied by its depth in feet, which will give the total weight on each square foot; and in the same manner the weight of a cubic foot of air in the upcast being multiplied by its depth will give the total pressure on each square foot in the upcast, and the difference between the two is then multiplied by the number of cubic feet of air circulating through the mine per minute, and the result divided by 33,000 will give the horse-power of the furnace. To illustrate this question, I will suppose the temperature in the downcast to be 50 degs., and that in the upcast 180 degs., and the depth of each shaft 1,000 ft., and also the barometer 30 in. By rule, $\frac{1{\cdot}3253 \times 30}{459 + 50} = {\cdot}0781 \times 1{,}000 =$ 78·10, total pressure in downcast. Again, $\frac{1{\cdot}3253 \times 30}{459 + 180} \times 1{,}000 = 62{\cdot}22$, total pressure in upcast. The difference of pressure would be 15·88 lb. × 70,000, the supposed quantity of air circulating through the mine per minute, and this result divided by 33,000 will give the horse-power of the furnace. Thus, $\frac{15{\cdot}88 \times 70{,}000}{33{,}000} = 33{\cdot}683$ horse-power.

255. If the horse-power of a furnace equals 8 and the ventilating pressure equals 3 lb. per square foot, what quantity of air is there circulating per minute?

The horse-power which produces ventilation is found by multiplying the quantity of air in cubic feet per minute by the ventilating pressure in pounds per square foot and dividing by 33,000, because pressure × area × velocity (that is, the total pressure × its motion in one minute) is always equal to pressure × quantity, and in this way the rule given is obtained. Now, if horse-power = 8 and ventilating pressure = 3 lb. per square foot, then the quantity of air which is being circulated $= \frac{8 \times 33{,}000}{3} =$ 88,000 cubic feet per minute.

256. Can you give the horse-power, &c., of any ventilating furnaces that have been constructed under your management?

The following table gives the horse-power of a small pair of furnaces put in by the author at the Rainford Collieries in 1877, worked out by the rule $W = \frac{1{\cdot}3253 \times H}{459 + T}$.

Horse-Power of Furnace.

Depth of downcast	240 ft.
Do. upcast	240 ft.
Temperature of downcast	50 degs.
Do. upcast	191 degs.
Air per minute	45,000 cubic feet.
Consumption of coal per minute	4·358 lb.
Quantity of air per pound of coal	10,325 cubic feet.
Horse-power expended	5·51
Do. per pound of coal used	1·266

257. Can you give a detailed description, with drawings, of the pair of ventilating furnaces referred to in the last question?

Yes; figs. 31, 32, 33, 34, 35, 36 and 37 are sketches of a small pair of ventilating furnaces designed by the author and referred to in the last question. Fig. 31 shows the front view; AA is the outside shell or arch of brickwork, three rings thick; around the outside of this, between it and the solid strata, is a layer of sand 12 in. in thickness, well packed to keep the heat from igniting the strata. Before putting in, the sand was screened through a very fine riddle to keep out all combustible substances, such as small pieces of coal, wood or cotton waste, &c. Under the arch, A A, is another arch, B, two rings thick, both arches being carried to the upcast shaft, as shown on ground plan (fig. 33). Between these two arches at C there is a space of 6 in. left, allowing the air to circulate through, and so keep the upper arch cool. Here and there a tie brick is put in to prevent the heat from expanding the inner arch. Under these two arches other two smaller ones are turned, one over each firegrate at F, and these are carried back 15 ft. D is a travelling road along one side of the furnaces, to facilitate the examination and repair of the furnace or drift at any time, there being an iron door fixed at either end to prevent air from passing through or the heat from striking back. Each firegrate is 6 ft. long and 3 ft. 7 in. wide. At the front of each grate is a pair of iron doors

SECTION OF FLANGES & BARS

Fig. 35

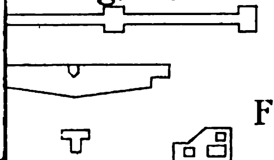
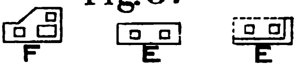


Fig. 37



Scale 1 in to 1 Yard

33.

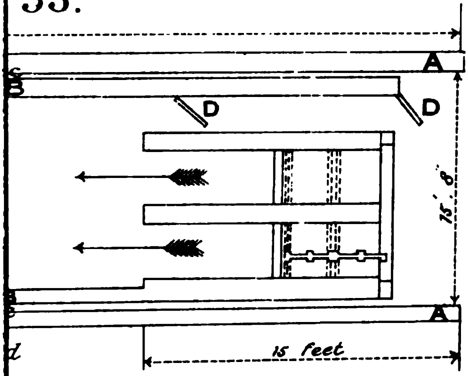
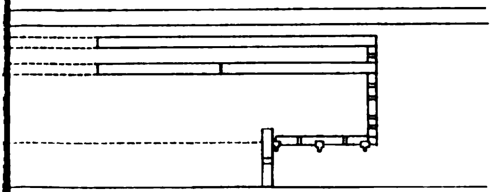


Fig. 32.



LONGITUDINAL SECTION

with four large holes in each door for the admission of air into the furnaces. Under each grate a wrought-iron pan is placed the full length and width of the grate, in which about 6 in. deep of water is constantly kept, so that all hot cinders dropping into them are immediately cooled. Fig. 32 is a section of the furnace and drift. Fig. 34 is a plan and section of the furnace drift and dumb-drift, showing the position of each in the upcast shaft. Fig. 35 is a plan and section of the furnace bars and bearers. In Lancashire, when sinking shafts, it is usually the custom to put in iron curbs in the upcast shaft, and as the author considers iron curbs preferable to wooden ones, he herewith gives a sketch of one. Fig. 36 is a plan and fig. 37 flanges, as shown at E E, and the section of a flange for an iron garland curb is shown at F.

258. Explain the difference between an exhaust fan and a force fan.

Fans can be made so as to either draw the air out of the mine or force it in. When they force the air into the mine they are called blow-fans, and are fixed at the top of the downcast shaft; exhaust fans are placed at the top of the upcast. The principle of the exhaust fan is as follows:—The action of the fan reduces the atmospheric pressure on the top of the upcast to a partial vacuum, the weight or pressure of the air in the downcast forces the air through the workings and up the upcast shaft to fill the vacuum caused by the action of the fan, and thus the air circulates in the mine.

259. Give your experience of such fans as have come under your notice.

Several types of fans are now in use, but the most generally adopted are the Guibal, the Schiele, and the Waddle. The Guibal fan is a machine of large size, and runs at a comparatively slow speed, the engine being generally coupled direct to the fan shaft. Although fairly successful as a ventilator, this fan presents several objectionable features, not the least being its great weight and bulk. The width of the Guibal fan varies from a quarter to half its diameter, and its weight is consequently spread over a considerable length of shaft, which it is impossible to support, except at the ends, and through defects in the shaft, unless made extra strong, considerable damage sometimes occurs, as well as loss of power by heating and grinding in the bearings. Another objection to the Guibal fan is the great amount of vibration, owing to its action being unbalanced. This type of fan also necessitates a large and costly erection of masonry to support its weight and to withstand vibration.

260. What do you mean by unbalanced action?

Simply this. The blades of the Guibal fan are parallel, and therefore discharge the air more rapidly at the circumference than it can be collected at the central inlet, by reason of the ever-increasing velocity at which the air travels from the centre to the circumference. Thus, a partial vacuum is created inside the fan, causing a "back lash," or backward suction of air to fill the vacuum, and vibration is the consequence, putting considerable strain on the working parts; this has doubtless been an important factor in causing the breakage of the main shafts of Guibal fans.

261. What are the leading features of the Schiele fan?

Small size, high speed and spiral casing. The air is conducted from the upcast shaft and enters the fan on both sides, the blades being riveted to a central disc. To a certain extent the blades resemble those of the Guibal, but instead of being bent forwards as in the Guibal, they are curved backwards into the circumference, in order to slip more easily through the air at the point of discharge. The discharged air ascends by a casing of gradually increasing area, thus diminishing the velocity of the discharge. A noticeable feature in the Schiele fan is that the blades taper towards the circumference and thus the bad effect of parallel blades is averted. Some persons object to the high speed at which the Schiele fan is driven, and its dependence on belt gearing, as well as to its high cost as compared with some other fans of equal capacities; but it is doing good work, a 14 ft. fan erected in South Wales having given 314,000 cubic feet of air per minute at 1·8 in. water-gauge. It is only fair to Messrs. Schiele and Co. to state that the fans made by them and also the engines are of sterling merit and splendid workmanship.

262. Give some particulars of the Waddle fan.

The Waddle fan is a machine of large diameter, working at a comparatively slow speed, the engine being usually coupled direct. Unlike the Guibal and Schiele, it has no fixed casing. Its air is collected at a central opening (generally about one-third of its entire diameter), and expelled direct from the blade tips. The blades are narrower at the circumference than at the inlet, being made with a gradual taper, which proportions the rate of discharge to that of collection (the area of the air passages remaining constant), preventing the back-lash common to fans of the Guibal type. By reason of this, the fan's action is perfectly balanced, the vibration entirely prevented, so that there is no danger in running this type of fan at the highest speed of which the engine is capable. The very little masonry required for a Waddle fan is no small argument in its favour. A fan of this type 35 ft. in diameter which has come under my notice has produced 120,000 cubic feet of air per minute at sixty-seven revolutions, with an average steam pressure in the cylinder of less than 17½ lb. per square inch, and maintained a water-gauge of 2·95 in. Another fan 30 ft. in diameter has been run at 100 revolutions per minute with perfect safety and no perceptible vibration.

263. Do you know of any open fan of smaller dimensions than the Waddle, and running at a higher speed?

The fan designed by Mr. J. Hayes, a mining engineer, who has given much careful study to the subject of ventilating fans, is illustrated in figs. 38 and 39. The Hayes open running fan has a central disc to which the blades are riveted, and, to maintain an equal area in the air passages of the fan, the blades are tapered, as in the Schiele and Waddle, by which means silence and absence of vibration in working are secured. The blades also have a uniform curvature from near the centre and curve backwards until they run into the circumference. This form of blade has been adopted to avoid the blow with which a flat surface would meet the air on its entrance to the fan, as well as the advantage which an inclined blade possesses in pushing the air towards the periphery of the fan, and the blades being curved backwards until they join the circumference, the

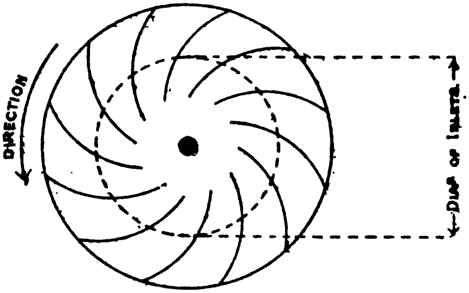


Fig 38.

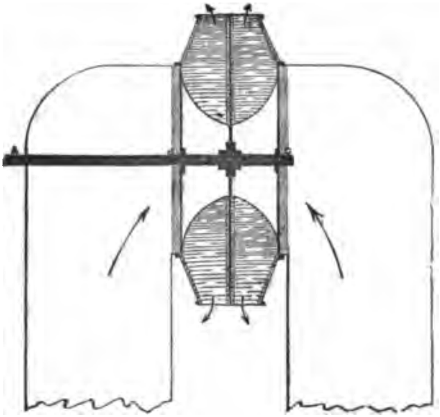
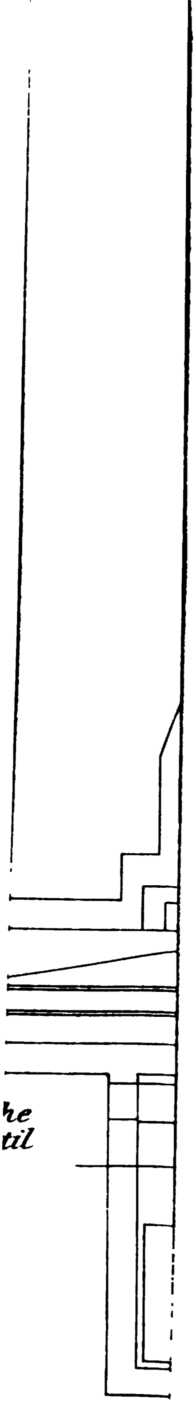


Fig. 39.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air is more easily slipped off than would be the case if the blades were flat. Another feature in this fan is the large double inlets. Air is admitted on both sides through inlets fully two-thirds the diameter of the entire fan, the superficial area of the combined inlets being almost equal to the superficial area of fan measured at its extreme diameter. Being of small size it is self-contained, and can be made very light by the employment of steel plates for the sides, blades and disc, and may be run at any speed with safety, power being conveyed from the engine by belt gearing or rope gearing, the latter method being advised. The simplicity of this fan, together with its low cost, should commend it. Mr. Hayes says:—"At a rough estimate, it may be assumed to do equal work with an ordinary Guibal or Waddle of three times its diameter." For collieries where the water-gauge is two inches and upwards the fan may, with advantage, be enclosed in a spiral casing of gradually increasing area.

264. What quantity of air will a Waddle fan 40 ft. diameter put in circulation, and also a 35 ft. Waddle fan.

The following are particulars of two tests supplied to the author by a mining engineer who has had great experience with the Waddle and other fans:—Result of Waddle ventilators: Fan No. 1, 40 ft. diameter, engine 32 in. cylinder × 48 in. stroke, 52 revolutions per minute = 225,000 cubic feet per minute, W.G. 2·5 in. Fan No. 2, 35 ft. diameter, engine 24 in. cylinder × 42 in. stroke, 67 revolutions per minute = 120,000 cubic feet per minute, W.G. 2·95 in; average steam pressure (indicated) 17½ lb. per square inch.

Figs. 40, 41, 42 and 43 are sketches of a Waddle fan erected by the author. Fig. 40 is a plan showing the fan in position, engine-house, fan-pit, and fan-drift. Figs. 41 and 42 are sections showing the fan in position, engine-house, fan-pit and fan-drift. Fig. 43 is a section through fan-pit. All dimensions are marked on the drawings for erection.

265. Do you know of any recent improvement in the Guibal fan ?

Yes. Mr. Charles Cockson's modification of the Guibal fan consists in tapering the blades from the inlet end to the tip, this tapering of the blade being so proportioned as to give an equal area of air passage throughout the fan. The first fan of this type was erected at the Dairy pit of the Wigan Coal and Iron Company. It is 30 ft. in diameter, has a close-fitting casing, expanding chimney and adjustable shutter, just like the Guibal, but the blades taper from 15 ft. wide at the inlet end of blade to 7 ft. at the tip. The engines, having cylinders 30 in. diameter and 36 in. stroke, drive the fan by grooved pulleys and rope gearing, so arranged that with the engines at 50 the fan travels at 80 revolutions per minute. Result of test was as follows: Fan at 75 revolutions ; air 230,092 cubic feet ; water-gauge at drifts 4·070, at fan 4·275, at pit top 4·025 ; horse-power in air 147·178, and horse-power in engines 196·4. The useful effect obtained in numerous trials varied from 70 to 75 per cent. The following advantages are claimed. On account of the less size and weight of the fan it is not so liable to break-down and injudicious straining, and it is for the same reason more economical than the ordinary Guibal. The fan is silent in action, vibration being practically absent. It is less costly to erect, on account of the less size of fan and casing, and requires less foundation and excavation. It can be made as small and light as the Schiele, and will give equal results at an average of two-thirds of the speed that would be required by the Schiele to do the same work.

266. Can you give a description of the Capell fan ?

This fan differs from others, having inner wings formed in a cylinder and driving the air collected in the cylinder at high centrifugal velocity through portholes of a certain proportionate area into the large chambers formed over the portholes by the outer wings. These chambers act, like the expanding chimney of the Guibal fan, in expanding the air but with this difference, that apart from the mere expansion which creates a water-gauge in the Guibal fixed chimney, there is a water-gauge already formed in them by

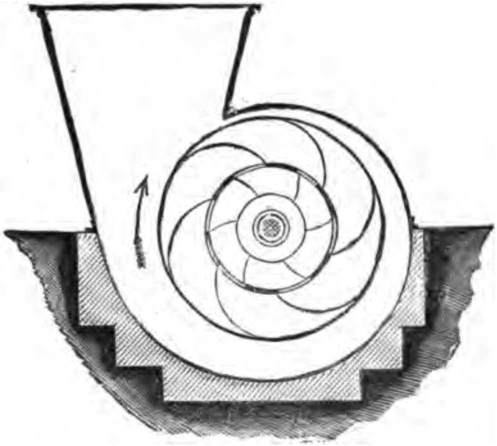


Fig. 44.

the revolutions of the fan. Both fans revolve together and form one rigid body. Since the introduction of the open-running fan of the double-power type, the inventor has

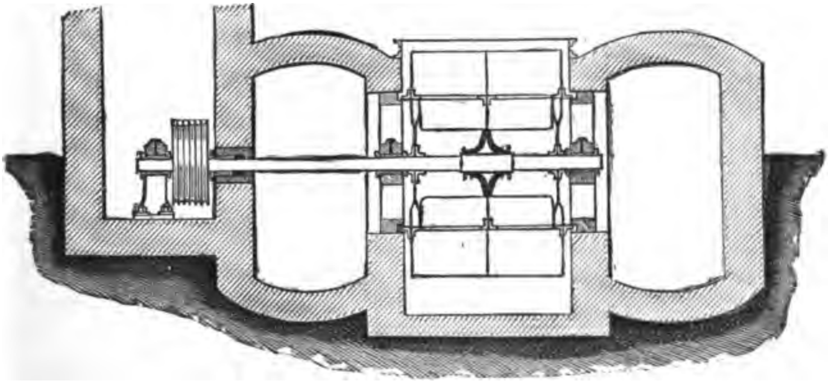


Fig. 45.

succeeded in introducing a double inlet enclosed ventilator (figs. 44 and 45). The following is a comparison of the action of the Capell, and the Guibal fan as designed by M. Guibal. Supposing the inlet velocity of the air to be 1,000 ft., under the regulating shutter, this is raised to 2,500 ft.; at the chimney top it becomes 900 ft. Thus the difference of air speed between the inlet and outlet is only 100 ft. But the total work done by a fan is the work at the inlet, plus the work at the final discharge into the air, but all the final work is to be deducted from useful effects. The Capell fan, enclosed type, instead of having a close-fitting case, has a spiral expanding case; one-third of the fan wheel is open to the *evasé* chimney. With an inlet speed of 1,000 ft., the outlet speed is about 600 ft., or 400 ft. less than the inlet speed; so that, apart from the restitution which takes place in the peculiarly-shaped chambers of the Capell fan, the work before the inlet must have a greatly less deduction made from its useful effect, for the work done in the final discharge of the air. It is declared that a 10 ft. double fan will be found to do better work than the 30 ft. Guibal fans of which the results have been recorded. The Capell patent fan can be driven direct at low speeds, or with gear at high speeds.

267. A Guibal fan is 20 ft. diameter with 8 ft. blades, and makes 50 revolutions per minute. What quantity of air would you expect to be put in circulation?

The quantity may be determined by the following formulæ, which is the outcome of actual experiments:—Let D = diameter of fan, B = breadth of blades, R = revolutions of fan, M = modulus, A' = deductions for centre. 20 × 20 ft., (D^2) = 400 × ·7854 = 314·1600 (area of fan) × 8 ft. (breadth blades) = 2,513·2800 cubic feet − (A') 100 = 2,413·2800 × 50 (revolutions of fan) = 120,664·0000 × (M) ·75 = 90,498 cubic feet per minute. Greatest possible effect, if no loss, about 90,000 cubic feet per minute in good circumstances.

[*The following illustrations of the efficiency of fans are added in this edition :*

(1.) A fan 10 ft. in diameter is making 120 revolutions and passing 20,000 cubic feet of air per minute through an airway 7 ft. × 6 ft., and 1,024 ft. long. What is the difference between the observed or actual depression (or water-gauge) and the theoretical ?

The following is the formula for ascertaining the theoretical water-gauge in inches :—

$$\text{W.G.} = \frac{u^2}{g} \times \frac{D}{d} \times 12.$$

u = the velocity of the periphery of fan in feet per second.
D = density of air at a temperature of about 60 degs.
d = density of water at a temperature of about 60 degs.
g = 32·2 nearly.

Now $u = \frac{10 \times 3·1416 \times 120}{60} = 62·2832$ ft. per second, and $\frac{D}{d} = \frac{1}{815}$. Therefore theoretically the water-gauge $= \frac{(62·28)^2 \times 12}{32·2 \times 815} = 1·778$ in.

The nearest approach to the actual water-gauge to be obtained from the data available and by the use of Atkinson's co-efficient of friction for air passing through mine passages is as follows :—

$p = \frac{k s v^2}{a}$ and water-gauge $= \frac{p}{5·2}$. Therefore water-gauge $= \frac{k s v^2}{5·2 \times a}$.

In this formula k = co-efficient of friction = ·0217, v = velocity of the air in thousands of feet per minute $= \frac{20}{42}$; a = area in square feet of the air-passage = 42 s ; = the rubbing surface in square feet = $(2 \times 6 + 2 \times 7) \times 1,024 = 26,624$.

Then the water-gauge $= \frac{·0217 \times 26,624 \times \left(\frac{20}{42}\right)^2}{42 \times 5·2}$ = ·5998 in. as compared with theoretical water-gauge of 1·773 in., which gives the proportion of $\frac{·5998}{1·773}$ or ·338.

(2.) A fan 12 ft. in diameter, making 100 revolutions per minute, and giving a depression of ·522 due to peripheral velocity, is passing 12,000 cubic feet of air per minute through an airway 7 ft. × 7 ft. and 5,131 ft. long: What is the proportion of depression used in putting the air through the fan and expelling it into the atmosphere, to the depression used in passing the air through the mine?

The following is the rule for working out the above question:—Height of water-gauge due to discharge of air $= \frac{u^2}{2g} \times \frac{1{\cdot}2 \times 12}{1{,}000}$ where $u = 12 \times 3{\cdot}1416 \times \frac{100}{60} = 62{\cdot}832 = \frac{(62{\cdot}832)^2 \times 1{\cdot}2 \times 12}{2 \times 32 \times 1{,}000} = {\cdot}888$ in. Height of water-gauge due to the friction in mine $= \frac{k\,s\,v^2}{5{\cdot}2\,a} = \frac{k\,s\,q^2}{5{\cdot}2 \times a^3 \times (1{,}000)^2} = \frac{{\cdot}0217 \times 28 \times 5{,}131 \times (12{,}000)^2}{5{\cdot}2 \times 49^3 \times (1{,}000)^2} = {\cdot}734$. Height of water-gauge due to the air passing through the fan is ·522, and that in the air in motion is ·888 in.; or the two together is 1·410 inches. Therefore, the proportion required $= \frac{1{\cdot}41}{{\cdot}734} = \frac{2}{1}$ nearly.

(3.) A fan 15 ft. in diameter is making 100 revolutions and passing 25,000 cubic feet of air per minute. What is the motive power, independent of engine and journal friction of fan expressed in foot-pounds per minute producing the current?

The following is the rule for working out of the above question:—Velocity of air per second $= 15 \times 3{\cdot}1416 \times \frac{100}{60} = 78{\cdot}54$ ft. Volume per second that is passed through the fan $= \frac{25{,}000}{60} = \frac{10{,}000}{24}$ cubic feet. Weight of $\frac{10{,}000}{24}$ cubic feet $= \frac{10{,}000}{24} \times {\cdot}080728$ lb. $= 33{\cdot}636$ lb. Units of work in air $= \frac{33{\cdot}636 \times 78{\cdot}54^2}{2 \times 32} = 3{,}241{\cdot}948$ foot-pounds per second. ∴ Units of work per minute $= 3{,}241{\cdot}948 \times 60 = 194{,}516{\cdot}88$ foot-pounds.

268. What is the general useful effect of fans?

The general useful effect obtained from fans is from 50 to 60 per cent. of the indicated horse-power of the engine.

269. If the horse-power of a fan be 30, and 35,000 cubic feet of air per minute are put in circulation, what would be the horse-power required, the quantity of air being increased to 100,000 cubic feet per minute?

Rule: The horse-power varies as the cube of the quantity thus:—$35{,}000^3 : 30 :: 100{,}000^3$.

$$\frac{100{,}000 \times 30}{35^3} = 702{\cdot}4 \text{ horse-power required.}$$

270. If the horse-power of a fan engine is 40, and the water-gauge is 1·5 in., what quantity of air would you expect to obtain, supposing the useful effect of the fan to be 50 per cent.?

In this case the horse-power in the air would be 20, and the rule is: The horse-power in the air $= \dfrac{\text{quantity} \times \text{W.G.} \times 5{\cdot}2}{33{,}000}$; the quantity for 20-horse power, with 1·5 water-gauge would be 84,615 cubic feet per minute.

$$\text{Thus: } \frac{20 \times 33{,}000}{1{\cdot}5 \times 5{\cdot}2} = 84{,}615.$$

271. If 84,615 cubic feet of air per minute pass through your workings with 1·5 water-gauge, what would be the useful effect of the fan or the horse-power of ventilation?

The useful effect of the ventilation would be 20-horse power nearly:—

$$\text{Thus: } \frac{84{,}615 \times 1{\cdot}5 \times 5{\cdot}2}{33{,}000} = 20\text{-horse power, nearly.}$$

272. If the horse-power of a fan engine is 16, and the water-gauge 1·25 in., what quantity of air would you expect to obtain, supposing the useful effect of the fan to be 50 per cent.?

In this case the horse-power in the air would be 8, and the rule is: The horse-power in the air = $\frac{\text{quantity} \times \text{W.G.} \times 5\cdot2}{33,000}$. The quantity for 8-horse power, with 1·25 water-gauge would be 40,615 cubic feet per minute.

$$\text{Thus: } \frac{8 \times 33,000}{1\cdot25 \times 5\cdot2} = 40,615.$$

273. If 40,615 cubic feet of air pass through your workings per minute with 1·25 water-gauge, what would be the useful effect of the fan or horse-power of ventilation?

The useful effect of the ventilation would be 8-horse power nearly:—

$$\text{Thus: } \frac{40,615 \times 1\cdot25 \times 5\cdot2}{33,000} = \text{8-horse power nearly.}$$

274. Which airway offers least resistance to the air, a circular one or a square one, and why?

A circular airway offers least resistance; the rubbing surface of a circular airway for the same length is less than any other form of equal sectional area, because the circumference of a circle is less in proportion than the perimeter of any other is to its area. A circle inscribed in a square is $\frac{7854}{10\cdot000}$ of its area. If we square the diameter of a circle we get a square whose area is to the area of the circle as 1 is to ·7854. Therefore, if we square the diameter and multiply by ·7854 we shall get the area, and the area multiplied into the length gives the contents. For instance, a circle whose area is 1, has a circumference of $\sqrt{1 \div \cdot07958} = 3\cdot545$, which is dividing the area by ·07958, and the square root of the quotient will be the circumference, which is equal to a little more than $\frac{1}{8}$. The perimeter of a square is 4 when its area is 1, so that about seven yards of square pipe will offer the same resistance as eight yards of round pipe having an equal size or area of section, when the same quantity of air passes through them in a given time.

275. Give some of the principal rules that must be observed in working out calculations on ventilation in mines under various circumstances.

The rubbing surface is found by multiplying the perimeter by the length; thus, a road 1,000 yards in length, and measuring 6 ft. × 5 ft. would have a rubbing surface (s) of (1,000 × 3 × 22) = 66,000 square feet. The quantity of air in cubic feet per minute is obtained by multiplying the velocity in feet per minute by the area. The horse-power is obtained by multiplying the quantity by the pressure and dividing by 33,000. The resistance is according to the length of the air-channel for the same quantity of air. Thus, if a mine were extended from 1,000 to 2,000 yards, the resistance would be doubled. The resistance is according to the square of the velocity, and aircourses having the same pressure, area and perimeter, but of different lengths, will pass quantities in accordance with the reciprocal of the square root of the length. Suppose an aircourse 200 yards long passes 7,071 cubic feet, the quantities that will pass in aircourses of 400 and 600 yards long, with the same pressure, area and perimeter, will be 5,000 and 4,082 respectively, because

$$\sqrt{\frac{1}{200}} = \cdot 07071 \,; \quad \sqrt{\frac{1}{400}} = \cdot 05 \,; \quad \sqrt{\frac{1}{600}} = \cdot 04082 \,;$$

and the fact that $l\,q^2$ for each airway gives the same result proves the correctness of the calculation. The quantity of air circulating in a mine is according to the square root of the pressure. In furnace ventilation the pressure increases with the depth (provided the difference of temperature between the two shafts be maintained) and the ventilation with the square root of the depth of the upcast, so that by adding a stack of 30 ft. at the top of an upcast 150 fathoms deep, the ventilation capabilities would be increased about 1-60th. The quantity of air passing is according to the cube root of the power applied, and *vice* *versâ.* The power necessary is according to the cube of the quantity; thus to treble the quantity of air in a mine, the power necessary would be twenty-seven times as much, and if by an expenditure of 70,087 units of work 16,848 cubic feet be obtained, the quantity that would be got by employing 277,045 units would be 26,639, because

$$\frac{16{,}848 \times \sqrt[3]{277{,}045}}{\sqrt[3]{70{,}087}} = 26{,}639.$$

The quantity of air passing in airways of different areas, other things being equal, is according to the square root of the area multiplied by the area. Thus, the pressure and rubbing surface being the same in each case, the quantity passing in an airway of 30 ft. area, when 20,000 ft. pass in one of 60 ft. area, will be 7,071, because—

$$\frac{\sqrt{30} \times 20{,}000}{\sqrt{60}} \times \frac{30}{60} = 7{,}071.$$

276. If you double the length of an airway, in what proportion will the friction be increased, all other things remaining the same?

The amount of friction is estimated by the amount of pressure or force required to overcome it. The rubbing surface is found by multiplying the perimeter by the length. Thus a road 1,000 yards in length, and measuring 10 ft. × 10 ft., would have a rubbing surface of 1,000 × 3 × 40 = 120,000 square feet. So the pressure required to propel air through a confined passage is proportional to the length of the passage; or, in other words, there must be a double pressure for a double distance, so that if we double or treble the extent of the rubbing surface, we also double or treble the friction.

277. What would be the rubbing surface of an airway 1,000 yards in length and measuring 4 ft. in height and 5 ft. wide?

The amount of friction or rubbing surface is estimated by the amount of pressure or force required to overcome it In this case the friction or rubbing surface would be 4 ×

$2 = 8 + 5 \times 2 = 18$ ft., or the perimeter by the length; thus, if a road were continued for 1,000 yards in length, and measuring 4 ft. × 5 ft. it would have a rubbing surface of $(1{,}000 \times 3 \times 18) = 54{,}000$ square feet.

278. If 10,000 cubic feet of air per minute pass through an airway 25 ft. area, what quantity will pass through if the airway is contracted to 20 ft. area by putting in a "regulator," everything else remaining the same?

The quantity that would pass through if the airway were contracted to 20 ft. area, everything else remaining the same, would be 7,156 ft. per minute. The quantity of air passing in airways of different areas, other things being equal, is according to the square root of the area multiplied by the area. Thus the pressure and rubbing surface being the same in each case, the quantity passing in an airway of 20 ft. area, when 10,000 ft. pass in one of 25 ft. area, will be 7,156, because $\frac{\sqrt{20} \times 10{,}000}{\sqrt{25}} \times \frac{20}{25} = 7{,}156.$

279. If 25,000 cubic feet of air per minute pass through an airway 42 ft. area, what quantity will pass through if the airway is contracted to 25 ft. area by putting in a regulator, the fan or furnace power remaining equal?

The pressure and rubbing surface being the same in each case, the quantity passing in an airway of 25 ft. area when 25,000 cubic feet pass in one of 42 ft. area will be 11,482·216; because

$$\frac{\sqrt{25} \times 25{,}000}{\sqrt{42}} \times \frac{25}{42} = 11{,}482{\cdot}216.$$

280. Would you get the greater amount of air from a deep pit or a shallow one by furnace ventilation?

By furnace ventilation it is reckoned that the quantity is as the square root of the difference between the temperatures of the downcast and upcast shafts, and also as the square root of the depth from the surface, so the higher the temperature and the greater the depth at which the furnace is placed, the greater will be the quantity of air it will put in circulation.

281. Give the number and size of furnaces that you would deem sufficient to set in circulation 60,000 cubic feet of air per minute, your upcast shaft to be 200 yards deep and 12 ft. in diameter, the furnace to be placed at the bottom of the same, and all other things being equal.

It would require two furnaces to set in circulation 60,000 cubic feet of air per minute, each furnace grate being 6 ft. long and 5 ft. broad; for it is found by practice that a well-constructed furnace will yield from 4,000 to 8,000 cubic feet of air per minute for each foot in breadth of bars, and taking the mean between the two, we shall have 6,000 × 10 (breadth of bars) = 60,000 cubic feet of air. In all cases the amount is as the square root of the difference between the temperatures of the downcast and upcast shafts, and also as the square root of the depth from the surface.

282. If you had two airways, one measuring 12 ft. by 4, and the other measuring 8 ft. by 8, each, say, 1,000 yards in length, would there be any difference of friction in the two airways; if so, give it. Also, suppose 1,000 cubic feet of air had to pass through each of these airways per minute; give the proportionate propelling power that would have to be applied to each.

The amount of friction is estimated by the amount of pressure or force required to overcome it. The pressure required to overcome the friction of air increases and decreases in the same proportion that the area or extent of rubbing surface exposed to the air increases or decreases. In this case the friction of the airways would be exactly the same, as the perimeter of each would be 32 ft., but the area of the larger airway is 8 × 8 = 64, while the area of the smaller one is only 4 × 12 = 48, or just three-fourths of the former; so that in the larger airway we shall only require to employ three-fourths of the pressure on each square foot of surface, the rubbing surface for an equal length of airway being the same in the two cases.

283. In what proportion will the pressure or head of air column have to be increased in proportion to the

increased length of airway to force the same quantity of air through an airway 2,000 yards long as through an airway 1,000 yards long?

The pressure required to propel air through a confined passage is proportional to the length of the passage, or, in other words, there must be a double pressure for a double distance.

284. In what proportion would the pressure have to increase to an increased velocity of air through an airway in the underground workings?

When air is impelled through a confined passage the pressure is proportional to the square of the velocity, so that to double the velocity there must be four times the pressure, or to treble it twenty-seven times the pressure, and so on. If we treble the velocity of the air we thereby cause three times the number of particles to meet the resistance in each moment of time; this alone will treble the resistance, and this, with three times the speed, may well be supposed to give rise to a treble treble or twenty-seven resistance.

285. In what proportion does the pressure vary in different sizes or areas of airways?

The pressure required to propel air through a confined passage is inversely proportional to the sectional area of the passage. Thus we will suppose an airway 4 ft. square and another 2 ft. square; the perimeter of the former would be 16 ft. and that of the latter 8 ft.; the larger airway would require double the amount of pressure for its double-sized perimeter, but this double pressure would propel four times the quantity, or in other words, the same expenditure of power on the 4 ft. airway would propel double the quantity it would force through the 2 ft. airway, or an equal quantity would be propelled by half the power.

286. Which do you consider should be the larger, your upcast shaft or downcast shaft, and why?

I consider the downcast shaft should be the larger. If the velocity of the currents in the downcast and upcast were equal, it would follow that the upcast must be in all cases a great deal larger than the downcast, because of the expanded volume of air; but inasmuch as the velocity increases equally with the expansion, it is found that the downcast should be the larger if there be any difference.

287. Can you quote any authority as to the respective sizes of upcast and downcast shafts?

Yes; Mr. Atkinson says, in his writings, if the ventilating pressure were independent of the area of the shafts and undivided airways near them, they should be made of the greatest practicable area, to ensure the best results in ventilation. This is the case, he says, with reference to a downcast shaft and all level airways, whatever may be the power employed, but when furnace ventilation happens to be the power made use of, there will probably exist a limit to the area of the furnace drift and upcast shaft, to exceed which would operate prejudicially on the ventilation of the mine, all other things being the same, inasmuch as the cooling of the air in the airways and shafts traversed by it passing over the furnace will become greater and greater as we enlarge their area, and thereby reduce the ventilating pressure. At the same time any enlargement of these airways must be attended with a reduction of their specific resistance, which would be to set against the increased loss by cooling. These, in fact, are leading elements for consideration in determining what is the best possible area of section to be given to upcast shafts, in order to realise the maximum ventilation by the consumption of a given quantity of fuel, when the power employed is that of furnaces. The object of having a ventilating furnace is to strengthen and guide the "natural" current. If there were no loss of heat in the upcast shaft the furnace would be the most economical means of ventilation. But as the ascending column of air becomes cooled by conduction through the sides of the shaft, there is always a loss of effect and greater or less according to the nature of the rock, the presence of water, the diameter of the upcast shaft, &c. In a lecture by Mr. H. Mackworth, reported in the *Colliery Guardian* in 1858, it is said:—"There is a great loss of heat by lateral conduction through the rock and walls of the shaft, and in wet shafts the loss of heat laterally occasionally amounts to four-fifths of the whole of the heat communicated." Speaking upon ventilation Mr. Hood says:—"In all methods of ventilation it is advisable to make the aggregate area of the openings that admit the fresh air larger than the aggregate openings for the efflux of the vitiated air. This becomes necessary," he says, "notwithstanding the increase of volume which takes place in the heated and vitiated air." This increased velocity does more than make up, by the accompanying increase of friction, for any reduction in such friction that is due to the lessened density of the air in every case. The friction, in fact, increases or decreases in just the same proportion that the volume of a given weight of air increases or decreases. If this is so, the same quantity of air could be passed through a 10 ft. upcast as through a 16 ft. upcast if the heat in the 10 ft. upcast were raised in proportion to the increased velocity. As Atkinson says, this increased velocity does more than make up by the accompanying increase of friction. The author has had many cases brought under his notice by well-known mining engineers where two pits have been sunk—one of 16 ft. in diameter, and the second 10 ft. diameter; when connected at the bottom the 10 ft. has become the upcast without the aid of any artificial appliances, and sometimes, when artificial means have been applied to make the 16 ft. the upcast, if these were discontinued the 10 ft. has again become the upcast.

288. Can you illustrate your theory as to the relative sizes of downcast and upcast?

Fig. 46 illustrates my theory. I have tried the experiment myself many times, and always with the same result—viz., that the current of air always travelled in the same direction. From A to B on the diagram in my experiment would be 19 ft. of a vertical column of pipes 6 in. diameter, and from B to C would be 19 ft. of a horizontal line of pipes

3 in. diameter, and from C to D would be 19 ft. of a vertical column of 3 in. pipes, all connected together. On putting a small fire underneath the horizontal line of pipes at E, which would be at equal distances from the two vertical columns, a current of air was set in circulation through the pipes as soon as they began to get warm, and the direction the current of air took was from A to D—that is, the large pipe became the downcast and the small one the upcast. This theory can easily be tested by contracting or scaffolding over the top of the upcast shaft, say, two-thirds of its area; it will be found that the same quantity of air, or nearly so, passes through the underground workings as before contracting the shaft, all other things remaining the same, but the reverse will be the case if the downcast is contracted two-thirds of its area. To prove my theory in practice, I will give a case in point. A short time ago I put a 30 ft. Waddle fan at the top of a 12 ft. upcast shaft; the downcast was a 12 ft. also, and in a few days after the fan was started to work I connected, by thirling at the bottoms, a third 12 ft. shaft, making two 12 ft. downcasts and one 12 ft. upcast. When the second 12 ft. downcast was connected it added 30,000 cubic feet of air per minute to the total quantity; this I account for by having a larger downcast pressure or power.

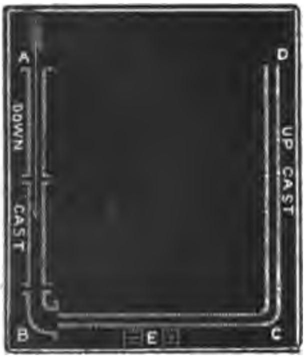


Fig. 46.

289. Which shaft do you consider should be the downcast—the larger or the smaller one—when fan ventilation is applied?

The downcast should be the larger if there is any difference, whatever may be the power employed. The ventilating fan placed at the top of the upcast only reduces the atmospheric pressure on the top of the upcast to a partial vacuum; the atmospheric pressure upon the top of the downcast then comes into operation, and forms a ventilating pressure or power, propelling the air through the airways and upcast shaft, and the greater the depth and diameter the greater will be the weight of the column of air in the downcast. This will be understood when we consider that a column of air 1 foot square and of the full height of the atmosphere weighs nearly 1 ton. Another column of air of the same height, and 1 inch square weighs only 14·75 lb. We must also take into account that the lower layers of air in the underground airways, and at the bottom of the downcast are compressed by the higher layers in the shaft, and the atmosphere above the shaft, and the greater the depth and diameter of the downcast the greater will be the compression. Air is also elastic—that is, it can be expanded by heat or by reducing the pressure at the top of the upcast. The ventilating fan would therefore create a larger vacuum at the top of a 10 ft. upcast than it would at the top of a 16 ft. upcast; consequently by making the 10 ft. the upcast and the 16 ft. the downcast, two natural powers would assist the ventilation, viz., a large column of air in the downcast (once put in motion is power), and the larger vacuum at the top of the upcast caused by the fan. The late J. J. Atkinson, speaking upon this point, says, "The intake air in dip or descendent workings acts as a ventilating power assisting any other ventilating power that may be in existence;" and as already quoted, that "the downcast should be made of the greatest practicable area."

290. Can you adduce any well-authenticated instance in practical working on the matter?

Yes; I am indebted to Mr. John Hayes, mining engineer, of Maryport, for the following interesting statement. Mr. Hayes says:—"I had an experience in sinking a new pit, and it is worth relating, as, so far as I am concerned, the idea is original. We had sunk about 230 yards, 13 ft. diameter to our seam. Air-boxes were conveyed from a mouthing into existing workings from another shaft about 170 yards deep, and having an area of 6 square feet. When we reached the coal we found no gas and commenced our level, which was driven about 14 yards on each side when gas in large quantities suddenly appeared. We had 40 or 50 yards to drive (part of it upbrow) to connect with our downcast shaft, the 13 ft. shaft being the upcast. I thereon put a steam jet in the upcast, which served our purpose until we began to drive upbrow, when we were clean beaten and there seemed nothing for it but to double our downcast air-boxes. However, the idea occurred to me, that by *your theory* the atmospheric pressure on the top of a 13 ft. shaft was almost if not quite sufficient to reverse the current under conditions of natural ventilation, and must of necessity greatly impede the efficiency of the steam jet, so I covered the shaft over with planks, leaving a hole about 4 ft. × 4ft. for the hoppit to travel through. The result was the atmospheric pressure was taken off an area of nearly 120 square feet and the upcast velocity through the hole very considerably increased. To the surprise of the men, whom I had only a few minutes before brought out of a very fiery atmosphere, we re-entered the place and could find no trace of gas anywhere. The necessity for doubling our air-boxes had gone, and this simple arrangement, made by recognising natural laws, carried us safely and efficiently through until we obtained the desired connection."

291. Can you give other instances?

Yes; Mr. William Blakemore, jun., mining engineer, of Aldridge, supplies me with the two following interesting and important accounts of cases dealt with by himself during late years, and which, I venture to submit to my readers, conclusively establish the correctness of my theory. In November 1881, a fire (the result of spontaneous combustion in the eye pillar) broke out at the Cannock and Wimblebury Colliery, Hednesford, within thirty yards of the bottom of the upcast shaft, as shown at point A on plan (fig. 47), and as the whole of the return current of air passed this spot, it was soon fanned into a flame, and rushing up the shaft, quickly converted it into something resembling a blast furnace. The shaft was 8 ft. 6 in. diameter, and 268 yards deep to the shallow coal where the fire broke out. The flame rushed out at the pit mouth, carrying pieces of burning wood and coal high into the air. " As this occurred in the night-time, only a few men were in the pit, and the overman, hoping to save the shaft, at once commenced to put in a dam at point B to stop the supply of air; but a new danger presented itself, illustrating the great effect of the " suction " of air—gas began

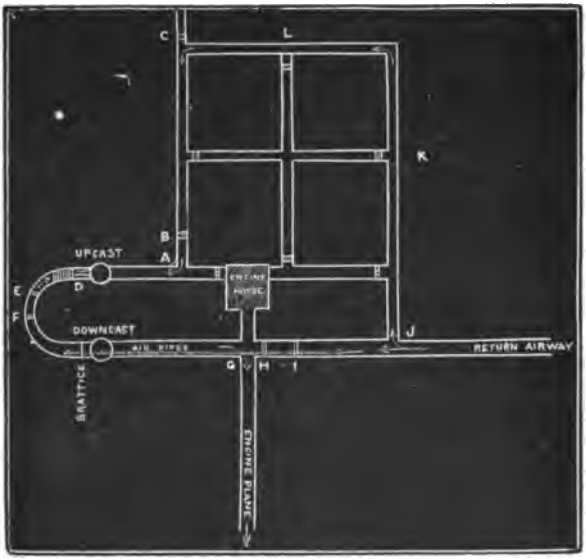


Fig. 47.

to issue from an old road at point C where it had not been seen for a long time; and, owing to the vastly increased rush of air to the upcast, it soon spread and filled the road between points B and C, and before the dam at B could be carried to the roof the gas passed over, and as this point was only ten yards from the fire, the workers reluctantly had to abandon their effort, and run for their lives, as an explosion was imminent. Meanwhile, the fire continued to rage furiously, and the sound of falling brick-work was a certain indication that the curbs were burnt out and the shaft giving way. As soon as the men were out, the downcast pit was scaffolded over about 5 yards below the top and filled up with clay. This caused the fire to subside at once, but as the brickwork continued to fall, and, owing to the smoke and heat, it was impossible to examine the upcast shaft, it was decided to fill it up—at any rate, far enough to admit of an inspection. This was done, and the next day it was ascertained that the shaft had literally "run in" for nearly 100 yards. This was filled up as quickly as possible, and took three days; on the fourth day the sinkers commenced to cleanse it out again, and renew the shaft. This work was proceeded with day and night, and the whole of the 100 yards stripped and made good in three months. Now the real difficulties began. The question was what was the state of affairs below. Unceasing efforts were made during the last month to re-enter the downcast pit. The scaffold was removed, and the shaft found to be full of smoke and gas to within a few yards of the top. A Schiele fan and several sets of air-pipes were tried, but all to no purpose. It was evident that one of two things must be done—either brattice the shaft all the way down and so make an upcast and downcast in the same shaft, or by some means connect the two shafts. But, of course, the problem was to do this without allowing the air-current to pass over the site of the fire, lest it should re-start it. The downcast was therefore scaffolded over again, and the cleansing in the upcast proceeded until it reached the mouth of the furnace arch at point D on plan, which was some six yards above the entrance to the shallow coal, and therefore free from the danger last alluded to. When this arch was cleared an entrance was cautiously made down the furnace chimney over the bars and along the dumb-drift to door E. A nail passer bored a hole through and explosive gas was expected, but none found. The door was then hastily smashed, and the explorers crawled to door F, where a similar experiment was repeated, but with a very different result, for carburetted hydrogen rushed through the hole with tremendous force—as one of the miners expressed it, "Like the tapping of a ginger beer bottle." It was now quite evident that the whole of the workings, some miles in extent, were filled with gas more or less explosive, and the only thing was to attach a chain to the door, carry the end back to the upcast pit, and fasten it to the winding rope for the purpose of bursting the door in safety. This was done, and three weary explorers crawled back in the dark with the gauzes of their lamps no longer steel blue, as at starting, but almost all the colours of the rainbow, from the action of the gas burning inside. The next step was to cleanse the scaffold in the downcast pit, and while this was being done, so great was the pressure of gas from beneath, that it forced itself through 6 ft. of dirt, and from this point the men had to work in darkness; at last, when only about 1 ft. of dirt remained, large spikes were driven through the dirt into several of the scaffold planks, and the winding rope attached, and simultaneously with the bursting of the door, F, through the medium of the upcast shaft the scaffold was broken in the downcast, and with a rush the air commenced to circulate. In half-an-hour the downcast was descended to the bottom, but not 3 ft. from the side of the shaft on the opposite side to the furnace-drift was an impassable barrier of carburetted hydrogen gas. Now the practical question, more particularly referred to, cropped up—How are these workings to be denuded of gas, having regard to their position, and remembering that the furnace drift was the only avenue to the upcast? First, the side of the downcast shaft was closely bratticed up, and a 2 ft. square wooden air-pipe inserted; this mouthing was extended about 6 ft. into the "inset," but all efforts to carry it further were unavailing. The gas did not budge an inch. Note that this was the result of trying to ventilate practically with a 2 ft. square intake or downcast, and an 8 ft. 6 in. shaft for upcast. Result: Absolute failure. Then the brattice was moved to the other side of the shaft—viz., to the furnace-drift side—and again the 2 ft. square pipe inserted, now forming the upcast, and the result was that as fast as 6 ft. lengths of the piping could be attached, the inset was cleared until point G was reached, which was the entrance to the main intake level to all the workings. The pipes were still continued, and most carefully inserted through doors H and I, which, it will be observed, at once placed the end of the pipes in connection with the return airway; instantly (in full justification of the design), the air commenced to circulate along the old channels down the engine plane at G all round the workings back to point J, and then, instead of going to the upcast, as formerly, by way of K, L, C, B and A, which, of course, was impossible, it entered the pipes at point I, and rushed away through the furnace-drift to the upcast. In six hours the whole mine was free from gas, and Mr. W. Blakemore and a company of explorers passed through every part of the workings. Result: Perfect success with a 13 ft. 6 in. downcast and a 2 ft. square upcast, unaided by artificial means of any kind." I cannot close this account without just saying that throughout all this dangerous and difficult operation no accident occurred, and the result certainly proved the correctness of the design, as well as the truth of the theory that I am upholding. The second case referred to was at the Leighswood Colliery, Aldridge, which was formerly worked by a company, but was put to stand in 1880. After standing two years, the colliery was acquired and re-started by the Aldridge Colliery Company. The work of re-entry and reopening was a dangerous and difficult one. There was a large area of workings in operation in the yard seam, 435 yards deep, and the deep and shallow seams 475, when the colliery was closed. The latter gives off explosive gas freely. "On an examination being made for the purposes of re-entry, it was found that the shaft was full of carburetted hydrogen gas to within fifty yards of the surface, and this had to be dealt with in one shaft (the downcast), as the upcast, being on another property, had not been acquired. First of all a Schiele fan 9 ft. diameter was procured and set to work by a 12 in. horizontal engine to blow through two sets of 12 in. air-pipes. The result was not very satisfactory, as little impression could be made on the gas, and this is not to be wondered at when we remember that the shaft was 13 ft. 6 in. diameter, and was for the time being converted into an upcast, as against a downcast of less than 2 square feet in area. During some days no progress could be made, and not a single air-pipe was added. At last, by dint of perseverance and constant running of the fan, a depth of 235 yards was reached. Time occupied, two months. At this point is a seam of coal known locally as the 7 ft., which was being worked at the No. 1 plant of the Aldridge Colliery Company, where the upcast shaft, intended for connection with the Leighswood Colliery, was situated. A heading was now driven from the face of work in this seam (a distance of 150 yards), and thirled into the Leighswood shaft. The effect was instantaneous; the gas was lowered to this level, and the fan and air-pipes were at once liberated. From the mouth of the heading bratticing was carried down the side of the shaft; and, although the area of the passage enclosed was only 8 square feet, it acted as a perfect upcast, and as fast as the brattice could be lengthened the gas was removed, and in five days the Yard seam at 435 yards was reached. And by means of the same arrangement the Yard seam was denuded of gas, and more than 200 yards of heading driven to connect this pit with the workings in the same seam at No. 1 plant, and this occupied about four months. Afterwards the brattice was utilised to clear the shaft below, and to partially re-open the deep and shallow seam, which was done with perfect success." These experiments place the principle for which we have been contending out of the region of mere theory, and justify us in regarding it as a well-established fact that if there is to be any difference in size between the downcast and upcast, the downcast should always be the larger of the two; and nothing could more conclusively and practically prove this than the important cases dealt with above. I do not think that, after carefully perusing the foregoing, any of my readers will need further proof, although it would be easy for me to multiply instances. I dismiss this part of the subject by reminding my readers of the old proverb that "an ounce of fact is worth a ton of argument."

292. If your workings were driven out 500 yards from the shaft, and with an overbalance of pressure of 10 lb. per square foot you got 70,000 cubic feet of air per minute, and you were to extend your workings to 1,000 yards, what extra pressure would you require to get the same amount of air?

If we double or treble the extent of the rubbing surface, we also double or treble the friction, or what is the same thing, the force or pressure required to overcome it must be doubled or trebled; so in this case, if an overbalance of pressure of 10 lb. per square foot puts in circulation 70,000 cubic feet of air per minute through an airway 500 yards long, it would require an overbalance of pressure of 20 lb. per square foot to set in circulation the same amount of air through an airway 1,000 yards long, all other circumstances remaining the same?

293. If you had an airway 8 ft. square, and with an overbalance of pressure of 10 lb. per square foot you set in circulation 30,000 cubic feet of air per minute, what

pressure would you require if the velocity were doubled, or 60,000 cubic feet of air passed through it per minute, all other circumstances remaining the same?

If we double the velocity of air in the same airway, we in the first place cause twice the quantity of air to meet the resistance in a given time, and in addition to this every part of this double quantity meets every resistance with a double velocity; so it will take 40 lb. pressure to the square foot to set in circulation 60,000 cubic feet of air per minute through the airway in which 10 lb. per square foot sets in circulation 30,000 cubic feet per minute.

294. What quantity of air would you deem necessary for each man and boy employed in the mines where no firedamp is given off, and what quantity where firedamp is given off?

Mr. Hedley, inspector of mines, says that where there is no escape of firedamp and little of any other mineral gas, 100 cubic feet of air per minute for each man and boy is the minimum quantity, and where firedamp is given off 500 cubic feet per minute for each collier.

295. Two drifts on the dip and two on the rise, and two levels, all the same distance from the shaft; which would be most easily ventilated, and why?

The drifts on the dip would be most easily ventilated, as the descending current of air on the dip would act as a power or pressure assisting the ventilation in the dip working; the levels next; and those on the rise would be much more difficult to ventilate than the others, as it will require a power or pressure to force air up bank, if it has to return to a low point again.

296. By what is splitting the air limited?

Splitting the air is limited by the area of the shaft. Owing to the resistance offered by the shafts, it would not be practicable to have more than a limited number of splits in a mine.

297. You have two dips or jigbrows setting up, and gas in them, you put brattice cloth to get it out; would you have your inlet on the broad side, or the narrow one?

I should always have the inlet on the broad side, so that the gas might pass out on the narrow side without coming in contact with the safety lamps or the men working on the broad side.

298. An airway of a given area, length, and perimeter discharges 30,000 cubic feet per minute; required first the total discharge on adding a similar airway, making total area, length, perimeter each; second, the power being constant, and supposing both airways to be 5 ft. by 10 ft., and 1,000 ft. long. Also give an illustration when the total discharge is 20,000 cubic feet per minute.

FIRST ILLUSTRATION.—

FIRST AIRWAY.

1. *Dimensions of airway.*—10 ft. wide, 5 ft. high (supposition).
2. *Area of airway.*—Width × height or 10 ft. × 5 ft. = 50 square feet (deduction).
3. *Perimeter of airway.*—(Width × 2) added to (height × 2) = 30 ft. (deduction).
4. *Length of airway.*—1,000 ft. (supposition).
5. *Rubbing surface.*—Length of airway × perimeter = 30,000 ft. (deduction).
6. *Volume or discharge.*—30,000 cubic feet per minute (given).
7. *Co-efficient of friction.*—·0217 cubic feet per minute (constant).
8. *Velocity.*—$\frac{\text{Volume}}{\text{area}}$ = velocity; or $\frac{30{,}000}{50}$ = 600 ft. = velocity (deduction). When the volume is unknown, the velocity is obtained from the following formula:—

   Velocity squared $= \frac{p\,a}{k\,s} = \frac{234{\cdot}36}{{\cdot}0217 \times 30{,}000} = {\cdot}36.$

   Therefore velocity $= \sqrt{{\cdot}36} = {\cdot}6$ (deduction).
9. *Total pressure.*—Total pressure is found thus:—Co-efficient of friction × rubbing surface × velocity squared, or, $·0217 \times 30{,}000 \times ·6^2 = 234·36$ (deduction).

10. *Pressure per square foot.*—Total pressure divided by area = pressure per square foot; or, $\frac{234 \cdot 36}{50} =$ 4·6872 = pressure per square foot (deduction).

TWO AIRWAYS (POWER BEING CONSTANT).

1. *Area.*—Assuming the first airway to be 10 ft. by 5 ft., which gives an area of 50 ft., the area for the two airways = (50 × 2) = 100 square feet.
2. *Velocity.*—Velocity is found from the following formula: $V^2 = \frac{\text{total pressure}}{\text{co-efficient of friction} \times \text{rubbing surface}}$ $= \frac{234 \cdot 36}{\cdot 0217 \times 60{,}000} = \frac{234 \cdot 36}{1{,}302} = \cdot 18$. Therefore $V = \sqrt{\cdot 18}$ = ·42426 in thousands of feet per minute; (·42426 × 1,000) = 424·26 = velocity in feet per minute.
3. *Volume.*—Area × velocity = volume, or (100 × 424·26) = 42,426 cubic feet (total volume).

SECOND ILLUSTRATION.—Discharge 20,000 cubic feet per minute.

FIRST AIRWAY.

1. *Dimensions of airway.*—10 ft. wide, 5 ft. high (supposition).
2. *Area of airway.*—Width × height, or 10 ft. × 5 ft. = 50 square feet (deduction).
3. *Perimeter of airway.*—(Width × 2) added to (height × 2) = 30 square feet (deduction).
4. *Length of airway.*—1,000 ft. (supposition).
5. *Rubbing surface.*—Length of airway × perimeter = 30,000 ft. (deduction).
6. *Volume or discharge.*—20,000 cubic feet per minute (given).
7. *Co-efficient of friction.*—·0217 (constant).

8. *Velocity.*—$\frac{\text{Volume}}{\text{area}}$ = velocity; or, $\frac{20{,}000}{50} = 400$ ft. = velocity (deduction). When the volume is unknown the velocity is obtained from the following formula: Velocity squared, $\frac{p\,a}{k\,s} = \frac{104{\cdot}16}{{\cdot}0217 \times 30{,}000} = {\cdot}16$; therefore velocity = $\sqrt{{\cdot}16} = {\cdot}4$.

9. *Total pressure.*—Total pressure is found thus:—Co-efficient of friction × rubbing surface × velocity squared, or $\cdot0217 \times 30{,}000 \times {\cdot}4^2 = 104{\cdot}16$ (deduction).

10. *Pressure per square foot.*—Total pressure divided by area = pressure per square foot; or $\frac{104{\cdot}16}{50}$ = 2·0832 lb. = pressure per square foot.

TWO AIRWAYS (POWER BEING CONSTANT).

1. *Area.*—Assuming the first airway to be 10 ft. by 5 ft., which gives an area of 50 ft., the area for the two airways = (50 × 2) = 100 square feet.

2. *Velocity.*—Velocity is found from the following formula: $V^2 = \frac{\text{total pressure}}{\text{co-efficient of friction} \times \text{rubbing surface}}$ $= \frac{104{\cdot}16}{{\cdot}0217 \times 60{,}000} = \frac{104{\cdot}16}{1{,}302} = {\cdot}08$; therefore V = $\sqrt{{\cdot}08} = {\cdot}2828$ in thousands of feet per minute. (·2828 × 1,000) = 282·8 = velocity in feet per minute.

3. *Volume.*—(Area × velocity) = volume; or, 100 × 282·8 = 28,280 cubic feet (total volume).

299. In two airways, one measuring 12 ft. by 6 ft., and the other 9 ft. by 9 ft., the perimeter in each being 36 ft., and with a pressure of 10 lb. per square foot, you get 40,000 cubic feet of air per minute through the airway 9 ft. square; what pressure would you require to get the same amount through the airway measuring 12 ft. by 6 ft.?

The pressure required to get the same quantity of air through the airway measuring 12 ft. by 6 ft. as through the one measuring 9 ft. by 9 ft. would be in inverse proportion to the square of the area, thus, $\frac{10 \times 81^2}{72^2} = 12{\cdot}65$, answer, or $12\frac{2}{3}$.

300. If 40,000 cubic feet of air per minute pass through an airway 9 ft. square, at what velocity is the air travelling?

The velocity of the air would be, 493·827 ft. per minute (lineal), thus:—$9^2 = 81$, and $40{,}000 \div 81 = 493{\cdot}827$. answer.

301. When air travels at the rate of six miles per hour, what is the velocity in feet per minute?

Rule: $\frac{6 \times 1{,}760 \times 3}{60} = 528$ ft. per minute.

302. When air travels at the rate of six miles per hour, what is the velocity in feet per second?

Rule: $\frac{6 \times 1{,}760 \times 3}{60 \times 60} = 8{\cdot}8$ ft. per second. Or thus, $\frac{6}{3{,}600} = {\cdot}00166$ miles per second; $\cdot 00166 \times 1{,}760 \times 3 = 8{\cdot}8$ ft. per second as before.

303. How may the velocity of the air passing in a mine be accurately measured?

To measure the velocity of an air current, an instrument termed an anemometer is used. Fig. 48 is a sketch of the best anemometer I know—Davis's patent self-timing anemometer. By holding the instrument for a few seconds in the current of air to be measured, it correctly indicates feet per second; it is exceedingly portable, being only 4 in. in diameter, and in general appearance much resembles the well-known Biram anemometer. Every colliery manager and engineer acknowledges the difficulty and inconvenience experienced in using the Biram anemometer, which necessitates the use of a watch, and unless assisted by a man to carry his lamp, he has to hold his anemometer, watch and lamp. The new instrument dispenses with the use of a watch or timer and also of a lamp carrier; and, when held up in the current of air, without loss of time, indicates the velocity per second. Like the Biram, it is held up with its back to the current of air to be measured, and on no account must the air enter from the face. When the vanes have revolved for a few seconds, the spring button at A is pressed, and the large hand then indicates feet per second. After reading, screw down the milled head at B, until the plunger A is relieved, after which unscrew the milled head as far as it will go, and the hands return to zero. Should the velocity be such that the hand travels more than one revolution, then read the inner circle of figures. The small hand shows whether the outer or inner circle should be read.

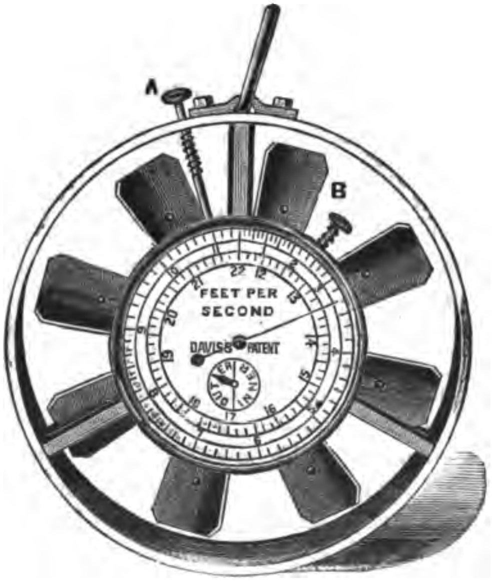


Fig. 48.

304. In an airway 8 ft. wide and 6 ft. high, registering by the anemometer 417 ft. per minute, what quantity of air per minute would be passing through the airway ?

The total quantity passing would be 20,000 cubic feet per minute. Rule: 8 × 6 = 48 area × 417 revolutions of anemometer = 20,016 cubic feet.

305. Give the dimensions, perimeter and area of an airway through which a current of 40,000 cubic feet of air per minute will pass at a velocity of 493·827 lineal feet per minute.

The following is the rule;—40,000 ÷ 493·827° = 81 ft. area, $\sqrt{81}$ square root = 9; or size of airway required is 9 ft. square, and the perimeter of airway is 9 × 4 = 36.

306. Give the dimensions, perimeter and area of two airways capable of passing 40,000 cubic feet of air per minute at a velocity of 493·827 lineal feet per minute.

The following is the rule:—40,000 ÷ 2 = 20,000 cubic feet passing through each, and 20,000 ÷ 493·827 = 40·5 ft. = area of each airway, and $\sqrt{40{\cdot}5}$ square root = 6·363; or the size of airway required is 6·363 ft. square, and 6·363 × 4 = 25·452, perimeter of each airway.

307. Give the dimensions, perimeter and area of two airways that would divide an airway passing 40,000 cubic feet per minute at a velocity of 500 lineal feet per minute into two equal splits, the velocity of each split still being 500 lineal feet per minute.

The following is the rule:—40,000 ÷ 2 = 20,000 cubic feet passing through each, and 20,000 ÷ 500 = 40 ft. = area of each airway required, and $\sqrt{40}$ square root = 6·324, or the airway would be 6·324 ft. square, and 6·324 × 4 = 25·296, perimeter of each airway.

308. Why is the constant 0·26881 taken for the co-efficient of friction?

From experiments it has been found that for every foot of rubbing surface in an airway, and for a velocity in the air of 1,000 ft. per minute, the friction is equal to 0·26881 ft. of air column of the same density as the flowing air, which is equal to a pressure, with air at 32 degs., of 0·0217 lb. per square foot of area of section; calling this the co-efficient of friction. The total pressure is found by multiplying the sectional area of the airways in feet by the pressure per square foot. To find the co-efficient of friction, divide the total pressure by the rubbing surface and the square of the velocity (in thousands of feet per minute) multiplied together. To find the velocity, divide the total pressure by the product of the co-efficient of friction and the rubbing surface; this gives the square of the velocity, the square root of which is the velocity itself, in thousands of feet per minute; this multiplied by 1,000 will give the velocity in feet per minute. It is better to take the velocity in thousands of feet per minute than in feet per minute. If it is preferred to take the velocity in feet per minute, in lieu of in thousands of feet per minute, the co-efficient of friction, in lieu of 0·26881 would become ·00000026881; and, if the velocity is taken in feet per second, it would become ·000967716.

309. If 40,000 cubic feet of air per minute are passing through an airway 9 ft. square at a velocity of 493·827 lineal feet per minute, what would be the horse-power of the same, supposing the length of airway to be 2,000 ft.?

The following is the rule for finding the horse-power expended:—4 × 9 = 36 × 2,000 = 72,000 square feet of rubbing surface, then 493·827 ÷ 1,000 = ·4938, the velocity in thousands of feet per minute; $\cdot 4938^2 = \cdot 24383844 \times \cdot 26881^k = \cdot 0655462110564 \times 72{,}000 = 4719\cdot 327196 \div 81 = 58\cdot 263 \times \cdot 080728$ lb. $= 4\cdot 703455464$ lb. $\times 40{,}000 = 188{,}138\cdot 2 \div 33{,}000 = 5\cdot 7$, or about 5¾-horse-power.

310. Find the difference of pressure or motive column when the temperature of air in the downcast shaft is 40 degrees, and that of the air in the upcast 78 degrees, the depth 1,000 ft.

The difference of pressure or motive column would be 70·8 ft. In this case the difference of temperature is 38 degrees, and hence we have $\frac{1{,}000 \times 38}{78 + 459} = 70\cdot 8$ ft. of motive column. Thus the pressure due to the difference in density of the air in the two shafts is that which would be got by a column of air of the density of that in the downcast shaft and 70·8 ft. in height.

311. Find the motive column where the upcast and downcast shafts are 380 ft. deep, and the temperature of the former is 120 degrees and the latter 45 degrees.

$$380 \times \frac{120 - 45}{120 + 459} = 49{\cdot}22, \text{ answer.}$$

312. What would be the total pressure in an airway 5 ft. square if the water-gauge registered 0·3 in.

The weight of a cubic inch of water is 0·036 lb.; so that when the column stands 1 in. high, the pressure is 0·036 lb. to the square inch, or 5·2 lb. to the square foot. Thus, if the water-gauge registered 0·3 inch, the total pressure on an airway 5 ft. square would be, $0{\cdot}3 \times 5{\cdot}2 \times (5 \times 5) = 39{\cdot}000$ lb. The water-gauge is used to show the force of the current generated by a ventilating fan or a furnace, and is, therefore, constantly referred to by the mining engineer.

313. If with a water-gauge of eight-tenths of an inch the quantity of air passing is 16,848 cubic feet, what quantity will pass when there is a water-gauge of 2 in.?

The quantity of air will be thus :—

$$\frac{\sqrt{2} \times 16{,}848}{\sqrt{\cdot 8}} = 26{,}639, \text{ answer.}$$

314. If the furnace and steam jets combined produce 46,706 cubic feet, and the furnace alone 42,670, what will the jets acting alone produce?

$$\sqrt{46{,}706^2 - 42{,}670^2} = 18{,}993, \text{ answer.}$$

315. If, with a water-gauge of ·72, we obtain 25,000 ft. of air per minute, what height will the water-gauge be when there is a quantity of 75,000 ft. of air passing?

The square of the quantity of air is proportional to the water-gauge, and as there is three times the quantity passing, the gauge will be $3^2 = 9$ times higher $= 9 \times {\cdot}72 = 6{\cdot}48$ in.

316. How would you apply the water-gauge to test the power of fan or furnace? Give a rule for calculating the same?

I should insert the water-gauge through the door or wall separating the intake from the return. The water-gauge taken in the fan drift at surface is not reliable, owing to the variable and whirling motions of the air given to it by the revolving of the fan. The rule is to multiply water-gauge by 5·2 lb., the pressure per square foot, and multiply this by the volume of air passing; the product divided by 33,000 gives the horse-power, or $\frac{p\,q}{33{,}000} = h$.

317. If the water-gauge shows 1·75 in. and the quantity of air passing through the airway is 70,000 cubic feet per minute, what is the horse-power produced in the ventilation?

Answer as per rule above. Thus: $\frac{1{\cdot}75 \times 5{\cdot}2 \times 70{,}000}{33{,}000}$ = 19·33-horse power.

318. How is the theoretical water-gauge of the centrifugal fan calculated?

The theoretical water-gauge of the perfect contrifugal fan is calculated by the formula $H_o = \frac{u^2}{g} \times \frac{d^1}{d} \times 12$; in which u is the velocity of the circumference in feet per second; g, force of gravity, or 32·19 ft. per second; d^1, density of air; d, density of water; and 12 is the number of inches in a foot. The value is never realised in practice, owing to the various imperfections inherent in different classes of centrifugal fans; and the expression becomes for the value of the initial water-gauge produced when the fan is exhausting from a closed chamber adjoining the inlet, $H = K\frac{u^2}{g} \times \frac{d^1}{d} \times 12$; in which K is a fraction representing the percentage of water-gauge utilised by the fan.

Example.—In a Guibal fan 30 ft. diameter, the initial water-gauge is ·676 of the theoretical water-gauge, and the orifice of discharge of the fan is 65 square feet. What will be the water-gauge and volume produced upon a mine whose equivalent orifice is 25 square feet when the fan is running at sixty-five revolutions per minute?

The value of u will be 102·1 ft. per second, and it is assumed that d^1, density of air, is ·0012, and d, density of water, is unity. The effective water-gauge will be

$$H = \frac{\cdot 676 \times 102\cdot 1^2 \times \cdot 0012 \times 12}{32\cdot 19 \times 1 \times \left(1 + \frac{25^2}{65^2}\right)} = 2\cdot 746 \text{ in.}$$

The volume produced per minute will be

$$V = 39 \times 25 \times 102\cdot 1 \sqrt{\frac{2 \times \cdot 676}{1 + \frac{25^2}{65^2}}}$$

$$= 108{,}833 \text{ cubic feet.}$$

The above formulæ are given by Mr. M. Walton Brown.

319. How much has the ventilating pressure to be increased to double the quantity of air?

Thus, $2^2 = 4$ times.

320. How much has the ventilating power to be increased to treble the quantity of air?

Thus, $3^3 = 27$ times.

321. If, by the application of 5-horse power, we obtain 30,000 ft. of air, what horse-power will be required to circulate 70,000 cubic feet?

If $30{,}000^3 : 5 :: 70{,}000^3 : 63\cdot 52$, answer; or, if $30{,}000 : \sqrt[3]{5} :: 70{,}000 = 3\cdot 9899$, and $3\cdot 9899^3 = 63\cdot 52$, answer.

322. If by applying 42,000 units of work we obtain 31,500 cubic feet of air, what power or units of work will be required to circulate 70,000 cubic feet?

As $31\,500^3 : 42{,}000 :: 70{,}000^3 : 460{,}905$ or cube root of $42{,}000 = 34\cdot 76027$; then say, as $31{,}500 : 34\cdot 76027 :: 70{,}000 : 77\cdot 245$ and $77\cdot 245^3 = 460{,}905$, answer.

APPENDIX TO CHAPTER VI.

Waddle and Guibal Fans.

As there has been considerable controversy concerning the Waddle and Guibal fans, the following, from a communication by Mr. G. Henger to the *Iron and Coal Trades Review*, is considered of sufficient interest to be inserted here.

Mr. Henger says:—We find that the committee appointed by the North of England Institute of Mining Engineers, in 1878, "with a view to place, as far as possible, on an impartial basis for comparison, the results of working, under ordinary conditions, of the principal ventilators at present employed for the ventilation of mines," has provided us with tabulated results which are supposed to demonstrate the superior efficiency of the Guibal fan. I hope, however, before concluding this communication, to prove, in the instances quoted, that the Guibal is very far behind the Waddle in efficiency, and for this purpose I shall give the following extract from the results referred to:—

In experiment No. 5 I have calculated the barometer at the bottom at the average rate of the others, namely, 1 in. for 900 ft., which gives 32·5.

It will be observed that, according to the table, experiments 5 and 2 give the highest percentage of useful effect; I shall therefore proceed to deal with these.

In all cases the percentage of useful effect is calculated on the indicated horse-power, and the horse-power calculated on the water-gauge at drift door, but in no case is the effect of the temperature taken into account or allowed for, and I therefore intend to calculate its effect and show how the efficiency is affected thereby.

To ascertain the water-gauge in No. 5, due to the difference of temperature alone, we may proceed by calculating the weight of a cubic foot of air in each shaft, multiplying the difference by the depth in feet, and dividing by 5·2.

Let I = height of barometer in inches, t = temperature of downcast, T = temperature of upcast, and D = depth in feet. Then we have—

$$\text{Water-gauge} = \left\{ \frac{1{\cdot}3253 \times \mathrm{I}}{459 + t} - \frac{1{\cdot}3253 \times \mathrm{I}}{459 + \mathrm{T}} \right\} \frac{\mathrm{D}}{5{\cdot}2}$$

$$= \left\{ \frac{511\,(1{\cdot}3253 \times \mathrm{I}) - 489\,(1{\cdot}3253 \times \mathrm{I})}{489 \times 511} \right\} \times \frac{1{,}890}{5{\cdot}2}$$

$$= \frac{22\,(1{\cdot}3253 \times 31{\cdot}5)}{489 \times 511} \times \frac{1{,}890}{5{\cdot}2}$$

= 1·336 in., which is the water-gauge due to temperature alone.

Having ascertained the water-gauge due to temperature, we may by the application of the accepted laws governing the circulation of air in mine passages, deduce the work due to temperature. The following are applicable:— $\sqrt[3]{p} : \sqrt[3]{P} :: q$, where p and P represent different powers, and q the quantity of air in cubic feet per minute. Again, $\sqrt{g} : \sqrt{G} :: q$, where g represents the water-gauge producing q and G corresponds to P. Then we have

$$\sqrt[3]{p} : \sqrt[3]{P} :: \sqrt{g} : \sqrt{G}.$$

The water-gauge of the fan and difference of temperature combined is 1·85 in. That due to temperature alone, as shown above, is 1·336 in. The quantity of air which the temperature alone would circulate is—

$$\sqrt{1{\cdot}85} : \sqrt{1{\cdot}336} :: 246{,}509 \text{ cubic feet},$$

or 209,480 cubic feet of air per minute due to temperature. The units of work due to temperature are

209,480 × 1·336 × 5·2= ... ... 1,455,299 ft. lb. or 44·09 h.p.
Total work of fan and temperature= 2,371,417 ft. lb. or 72·16 h.p.

Therefore the work performed by the fan alone is only 28·07 h.p.

For the benefit of such of your readers as are students of ventilation I will check this result and the method of establishing it by ascertaining the water-gauge which the fan alone with the same expenditure of power would produce and the quantity to be obtained therewith.

The total power calculated on water-gauge at drift door is 72·16 horse-power, and that of the fan is 28·07 horse-power. Then the quantity which fan alone would produce is

$$\sqrt[3]{72{\cdot}16} : \sqrt[3]{28{\cdot}07} :: 246{,}509,$$

which gives us 179,961 cubic feet of air. The square root of water-gauge varies as cube root of power

$$\therefore \sqrt[3]{72{\cdot}16} : \sqrt[3]{28{\cdot}07} :: \sqrt{1{\cdot}85} = {\cdot}9929,$$

and this squared gives ·9198 in. water-gauge, which fan alone would produce with expenditure of 28·07 horse-power.

The units of work performed by fan, if alone, are ·9198 × 5·2 × 179,961, or 860,745. Work of temperature is 1·336 × 5·2 × 209,480, or 1,495,299. The two added together give 2,356,044 units of work. When fan and temperature are operating together, we have 2,371,416 units of work (1·85 × 5·2 × 246,509), which nearly agrees. The slight discrepancy between the two is attributable to the roots not being worked out far enough, but the result is sufficiently near to demonstrate the accuracy of the method, the difference being only a fraction of a horse-power.

We have now established the horse-power of the fan in the drift assisting the ventilation at ·28·07. The indicated horse-power is 136·15, and therefore the useful effect is only 28·23 per cent.

In the second experiment in the table we get the following results:—Water-gauge due to temperature alone is

$$\left(\frac{1{\cdot}3253 \times \mathrm{I}}{459 + t} - \frac{1{\cdot}3253 \times \mathrm{I}}{459 + \mathrm{T}}\right)\frac{1{,}074}{5{\cdot}2} = \frac{9(1{\cdot}3253 \times 30{\cdot}5)}{512 \times 521} \times \frac{1{,}074}{5{\cdot}2}$$

= ·282 of an inch.

Then we have the square root of water-gauge varying as cube root of power

$$\because \sqrt{3{\cdot}08} : \sqrt{{\cdot}282} :: \sqrt[3]{79{\cdot}26} = \frac{{\cdot}5313}{1{\cdot}755} \sqrt[3]{79{\cdot}26}$$

and this cubed gives the horse-power due to temperature, which will be found to be 2·19. The remainder 79·26—2·19 = 77·07 is the horse-power due to fan, and is equivalent to 51·33 of useful effect.

Undoubtedly the particulars of the experments quoted above are thoroughly reliable, the carrying out thereof being entrusted to the care of the two engineers, Messrs. Lindsay and Liveing, but the conclusions based on the facts, as I think I have clearly shown, are not at all trustworthy, but on the contrary, they are directly opposed to these results. It is surprising that such an important factor as the temperature of the mines, after being carefully observed and tabulated, should not have been taken into account in the calculations, and that the effect of the difference should have been altogether ignored in the conclusions based thereon. It seems strange that so eminent a body of engineers should have accepted these tables without noticing this important omission.

A glance down the temperatures of the remaining experiments will show at once that large deductions are to be made in all cases, and that all the fans there referred to will consequently fall considerably below the Waddle in efficiency. I should think that these fans are all good specimens of their class, and that no objection could be raised on that head.

TABULATED RESULTS OF EXPERIMENTS MADE BY MEMBERS OF THE NORTH OF ENGLAND INSTITUTE.

Where situate.	Description and dimensions of ventilator.	Indicated horse-power of engine.	Horse-power in air. *	Per-cntge. of useful effect.	W.G. on drift door.	Barometer.		Depth.		Temperature.					Quantity of air in dr per minute.
										Upcast.			Downcast.		
						Top.	Botm.	Up-cast.	D'wn-cast.	Top.	Botm.	Av ge.	Top.	Botm.	
					In.	In.	In.	Fms.	Fms.	Degs.	Degs.	Degs.	Degs.	Degs.	Cub. ft.
Hilda Colliery, South Shields	Guibal, 50′ × 12′...	133·4	53·5	40·	3·30	29·87	31·37	142	215	78	76½	77¼	54	—	108,422
Celynen Colliery, S. Wales	Waddle, 45′ × 6′ 6″ and 1′ 3″	150·12	79·26	52·79	3·08	29·90	31·10	179	177	62	62	62	53	53	163,312
Carr House Colliery, Rotherham	Schiele, 9′ 6″ × 1′ 8″ and 3′ 2″	69·30	34·14	49·27	2·03	30·27	30·60	65	100	57½	57½	57½	37	37	106,570
Cortonwood Colliery, Barnsley	Schiele, 12′ × 2′ 1″	102·56	47·30	46·12	1·91	30·18	30·91	106	106	61	58	59½	40	40	157,176
Pemberton Colliery, Wigan	Guibal, 46′ × 14′ 10″	136·15	72·16	52·95	1·85	30·45	—	315	315	56	48	52	30	30	246,509
Cannock Wood Colliery, Staffordshire	Guibal, 40′ × 12′...	82·16	39·40	47·95	1·46	29·21	29·95	100	100	62	60	61	32	32	170,581

* Calculated on water-gauge at drift door,

The first General Rule of the Coal Mines Regulation Act, 1887, requires that the quantity of air in the respective splits or currents shall, at least once every month, be measured and entered in a book to be kept for the purpose at the mine.

RECORD OF VENTILATION AND OF METEOROLOGICAL OBSERVATIONS.

Coal Mines Regulation Act, 1887.—General Rules 1 and 33.

.... Colliery. .... Pit.

Date.	Time when taken.	Direction of Wind.	State of Weather.	At Surface.		Underground.		Water-gauge in Fanhouse.	Name of Station or Split.	Water-gauge at Separation Doors.	Sectio Area Airwa place Measur
				Bar.	Ther.	Bar.	Ther.				

The following form has been designed by the author for recording Ventilation and Meteorological Observations, and is published by W. M. Hutchings, London, who now holds the copyright. The full size of the form is 16½ in. by 6½ in., and the book as published contains 100 forms.

cast Shaft.—Dia. .... **Depth** .... **Dia. of Fan** .... **Revolutions per Min.** ....

pcast Shaft.—Dia. .... **Depth** .... **Or State of Furnace.**

lutions of nometer per inute.	No. of Cubic Feet of Air per minute.	Length of Airways in each District or Split.	Average number of Persons employed Daily.	Temperature of Main Return.	Remarks.	Signature.

CHAPTER VII.

VARIETIES OF COAL AND OTHER FUEL.

323. What is coal?

Coal is a carbonaceous substance found lying in strata at various depths beneath the surface of the earth.

324. What varieties of coal are there?

Coal may be arranged under five classes:—First, anthracite or blind coal; second, dry bituminous coal; third, bituminous caking coal; fourth, long flaming or cannel coal; fifth, lignite or brown coal.

325. Give the composition and characteristics of anthracite or blind coal.

Anthracite or blind coal is extremely hard, dense and strong; has a shining conchoidal fracture, and does not soil the fingers. Its specific gravity is very high—indeed, higher than any other coal—viz., from 1·35 to 1·92. In composition it contains carbon in great proportion, generally from 90 to 95 per cent.; about 3 per cent. hydrogen and oxygen, nitrogen and earthy substances in minute quantities. It is less easily kindled than any other kind of coal, and often decrepitates much in burning. It burns without flame or smoke, or the emission of sulphur. Anthracite is much used in the manufacture of zinc, in the distillation of which the purest form of carbon, compatible with economy, is required.

326. How many units of heat will a pound of anthracite coal produce?

A pound of anthracite will evaporate from 7·3 to 10·5 lb. of water at 212 degs. temperature; the latent heat in steam is 965 degs.; therefore a pound of coal will produce from

7·5 × 965 = 7,000 to 10·5 × 965 = 10,000 units of heat. Theoretically a pound of coal, containing 90 per cent. of carbon, will produce 12,800 units of heat. This is calculated on the assumption that a pound of carbon will produce 14,220 units of heat.

327. How much phosphorus do coal and cannel contain?

According to M. Carnot, coal, unorganised, examined in bulk, does not contain much phosphorus, although the proportion varies in different localities. On the other hand, the cannel with which it is associated contains a much more considerable quantity of phosphorus. The difference was first observed in samples from Commentry; and specimens of coals and cannels from other deposits were procured, in order to see if the same results held good. The following are the proportions determined by analysis:—Lancashire cannel, 0·02852; Wigan cannel, 0·02246; Newcastle cannel, trace; Glasgow cannel, 0·00572; Virginia cannel, 0·02771; naphtha schist of New South Wales, 0·01956; Autun-Boghead (free from fish scales), trace; Frioul-Boghead (Austria), 0·06275. All these cannels, except the last two, belong to the carboniferous deposits. Microscopic observations upon thin plates of cannel show this substance to have been formed of accumulations of decomposed vegetable matter of very diverse nature. There can, however, be detected in it, oftener than anything else, a considerable number of spores or pollen grains, generally very irregularly scattered. M. Carnot thinks that to these may be attributed the high but irregular proportion of phosphorus in cannel coal.

328. Describe dry bituminous coal.

Dry bituminous coals are rather lighter than the anthracites, varying in specific gravity from 1·28 to 1·44. They contain a relatively small proportion of volatilisable matter—about 15 per cent.—and soon arrive at the temperature of full ignition. Coals of this class swell very considerably in coking.

329. Describe bituminous caking coals.

These coals contain a maximum proportion of volatilisable matter, averaging about 30 per cent. of their whole weight, and have the same range of specific gravity as dry bituminous coal. They develope much of the hydrocarbon gases and burn with a long flame.

330. What is the principal chemical element in coal?

Carbon.

331. Name some of the principal countries where coal has been found.

England, France, Germany, Sweden, America, Australia and India.

332. Where is the best quality of coal found?

In Great Britain.

333. Which are the least inflammable coals found in Great Britain?

The Welsh coals.

334. Are all coals of the same chemical composition?

No; there are very great differences in the chemical composition and properties of coals. British coals may vary as follows:—Carbon from about 70 to 91 per cent. of the gross weight, hydrogen from 3½ to 7 per cent., oxygen from about ½ to 20 per cent., nitrogen from a mere trace to 2⅛ per cent., sulphur from nothing to 5 per cent., ash from ⅛ to 15 per cent., coke from 49 to 93 per cent.

335. What is the origin of coal?

It is of vegetable origin.

336. What is meant by bituminous coal?

Coal which gives off smoke and flame in burning.

337. What is meant by free-burning coal?

A free-burning coal is one that does not bind when burning, and is called steam coal.

338. What class of coal makes the best coke?

Bituminous—the anthracite class not having sufficient bitumen to bind the coal together.

339. What is the composition of pure coke?

For all purposes, the less ash there is in coke, the more valuable it is. Pure coke, if such there be, consists entirely of carbon. But in practice coke consists of carbon, sulphur and ash.

340. Give an analysis of the purest coke known.

The purest coke known is Ramsay's Garesfield coke. The composition, as ascertained by analysis by Dr. Richardson, is as follows:—

Carbon	97·6	per cent.
Sulphur	0·85	„
Ash	1·55	„
	100·00	

341. Can you give the composition of other cokes?

The composition of Durham cokes varies within the following limit:—

Carbon	85 to 92	per cent.
Sulphur	¼ to 2	„
Ash	4 to 12	„

Dr. Muspratt gives the results of nineteen analyses, as contained in the following table, arranged in the order of the percentages of carbon, the first in the table being Ramsay's coke, before referred to:—

No of coke.	Composition.			No. of coke.	Composition.		
	Carbon.	Sulphur.	Ash.		Carbon.	Sulphur.	Ash.
	Per cent.	Per cent.	Per cent.		Per cent.	Per cent.	Per cent.
1	97·60	0·85	1·55	13	91·49	1·46	7·05
2	96·42	0·83	2·75	14	91·16	1·19	7·65
3	95·51	1·64	2·85	15	90·53	1·01	8·46
4	94·67	1·07	4·26	16	89·87	1·78	8·35
5	94·31	0·72	4·97	17	89·69	1·96	8·35
6	94·21	0·69	5·10	18	85·85	2·08	12·07
7	94·08	0·88	5·04	19	84·82	0·78	14·40
8	93·54	0·76	5·70				
9	93·41	0·79	5·80	Averages of 19 cokes.	93·44	1·22	5·34
10	93·05	1·58	5·37				
11	92·70	1·60	5·70				
12	92·44	1·56	6·00				

342. Can you give the chemical analyses of some of the Welsh coals?

The following are analyses of some of the principal Welsh coals, with dates:—

Class of Coal and date of Analysis.	Carbon.	Hydrogen.	Nitrogen.	Sulphur.	Oxygen.	Ash.	Coke.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Ebbw Vale, 1848	89·78	5·15	2·16	1·02	·39	1·50	77·5
Powell's Duffryn, 1848	88·26	4·66	1·45	1·77	·60	3·26	84·3
Llangennech, 1848 ...	85·46	4·20	1·07	·29	2·44	6·54	83·7
Llangennech, 1871 ...	84·97	4·26	1·45	·42	3·50	5·40	86·7
Graigola, 1848	84·87	3·84	·41	·45	7·19	1·50	85·5

343. Give the composition of Torbane Hill or Boghead coal.

In composition Boghead coal occupies the opposite end of the scale to anthracite, having a comparatively small percentage of carbon and a large excess of hydrogen. According to Dr. Penny's analysis of the coal dried at 212 degs., its composition is—Carbon, per cent., 63·94; hydrogen, 8·86; nitrogen, 0·96; sulphur, 0·32; oxygen, 4·70; ash, 21·22.

344. Give a proportional analysis of some of the American coals.

The constituents, so far as analysis by Mr. W. R. Johnson extended, are in the following proportions:—

	Per cent.		Per cent.
Volatile matter other than moisture	2⅛ to 34½	average	16·17
Hygrometric moisture	0 to 8⅛	„	1·37
Sulphur	0 to 2⅛	„	0·49
Fixed carbon...	53 to 91	„	73·35
Earthy matter	4½ to 15	„	9·15

345. Give the composition of some of the French coals, showing also their specific gravity, heating power, &c.

TABLE SHOWING THE SPECIFIC GRAVITY, HEATING POWER AND COMPOSITION OF FRENCH COALS.

COALS. Regnault, 22 samples. Marsilly, 79 samples.	Specific gravity.	Quantity of coke.	Composition.				Hydrogen in excess.	Heating power.
			Carbon.	Hydrogen.	Oxygen and nitrogen.	Ash.		
REGNAULT.		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Units of heat.
Anthracites	1·498	88·83	86·17	2·67	2·85	8·56	2·43	14,038
Bituminous hard coals ...	1·319	74·81	88·56	4·88	4·38	2·19	4·27	15,525
Bituminous caking coals ...	1·293	67·54	87·73	5·08	5·65	1·54	4·30	15,422
Bituminous coals, long flame	1·303	60·86	82·94	5·35	8·63	3·08	4·15	14,622
Dry coals, long flame ...	1·362	54·72	76·48	5·23	16·01	2·28	3·09	13,041
MARSILLY.								
Mons Basin	1·265	71·50	83·85	5·19	8·09	2·85	4·24	14,884
Mons Centre Basin	1·293	81·79	86·38	4·51	5·46	3·66	3·82	14,931
Charleroi Basin	1·197	86·58	86·65	4·18	5·23	3·95	3·52	14,787
Valenciennes Basin	1·289	80·75	86·50	4·52	5·39	3·52	3·85	14,976
Calais Basin	1·280	74·66	84·94	5·15	7·02	2·93	4·22	15,003
Average	1·310	74·20	85·02	4·48	6·87	3·46	3·79	14,723

346. What is lignite?

Lignite, or as it is occasionally called, brown coal (though it is often found of a black colour) belongs to a more recent formation than coal; it is in fact an imperfect coal. Brown lignite is sometimes of a woody texture and sometimes earthy; black lignite is of the former kind.

347. What is asphalte?

Asphalte, like lignite, contains a large proportion of hydrogen, and is of the same origin.

348. Give the composition of lignite and asphalte.

The average composition of lignite and asphalte may be taken in whole numbers, as follows:—

	Lignite.	Asphalte.
Carbon .... per cent.	69	79
Hydrogen........................	5	9
Oxygen and Nitrogen.........	20	9
Ash	6	3
	100	100

349. What is wood-charcoal?

When wood is exposed to heat, it is first desiccated and afterwards carbonised under temperatures up to 300 degs. Fahr. The wood yields a charcoal, which is black, solid and brittle. The composition of charcoals varies with the temperature at which they are produced.

350. What is peat?

Peat is the organic matter or vegetable soil of bogs, swamps and marshes, decayed mosses or sphagnums, sedges, coarse grass, &c., and is found in beds from 1 to 40 ft. deep.

351. What percentage of water does peat generally contain?

Peat, in its natural condition, generally contains from 75 to 80 per cent. of its entire weight of water.

352. Give the composition of some varieties of peat.

The following table gives the composition of some of the Irish peats taken as perfectly dry.

Description and locality of Peat.	Specific Gravity.	Carbon.	Hydrogen.	Oxygen.	Nitrogen.	Ash.
		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
1. Light surface, Philipstown ...	·405	57·52	6·83	32·23	1·42	1·99
2. Rather dense, do. ...	·609	58·56	5·91	31·40	·85	3·30
3. Light surface, Wood of Allen	·335	58·30	6·43	31·36	1·22	2·74
4. Compact and dense, do.	·655	56·34	4·81	30·20	·74	7·90
5. Light fibrous, Ticknevin	·500	58·60	6·55	30·50	1·84	2·63
6. Light fibrous, Upper Shannon	·280	58·53	5·73	32·32	·93	2·47
7. Very dense, compact do.	·853	59·42	5·49	30·50	1·64	2·97
Averages	·528	58·18	5·96	31·21	1·23	3·43

353. What is artificial or patent fuel?

It is a mixture of small coal with coal-tar, peat, &c.

354. Can you give the mixture of any patent fuel?

The best known patent fuel is that of Warlich, which is a mixture of small coal and tar or pitch moulded into blocks. Each ton of small coal is mixed with 22 gallons or 242 lb. of tar. It is then formed into blocks, and packed at a temperature of 800 degs. Fahr. for about 19 or 20 hours.

355. Do you know of any other mixture of patent fuel?

The manufacturers of patent fuel have each their own formula, but the following two, with the one previously mentioned, are the most important for the utilisation of small coal. Wylam's fuel is prepared by mixing with slack about 7 or 8 per cent. of its weight of pitch in a dry state ground fine. Mezaline's fuel, like Wylam's, is a mixture of slack and ground fine in a pug mill?

356. Give a good table of the average heating power of fuels generally.

The following table gives the heating power of fuels:—

No.	Fuel.	Heating power of a pound of fuel.	
		Units of heat.	Water evaporated per pound of fuel from and at 212° Fahr.
		Units.	Lb.
1	Warlich's Fuel	16,495	17·07
	Units. Lb.		
	Coal:—Ebbw Vale, 1848, 16,221 16·79		
	Powell's Duffryn, 1848, 17,715 16·25		
	Llangennech, 1848-71, 14,765 15·28		
2	Average (best Welsh) 15,567 16·11	15,567	16·11
3	Haswell Wallsend (Newcastle)	15,502	16·04
4	British coals, average	14,133	14·63
5	Coke	13,550	14·02
6	Lignite, perfect	11,678	12·10
7	Asphalte	16,655	17·24
8	Wood, perfectly dry...	7,792	8·07
9	Do. 25 per cent. moisture	5,565	5·80
10	Wood charcoal, dry	12,696	13·13
11	Peat, perfectly dry	9,951	10·30
12	Do. 25 per cent. moisture	7,156	7·41
13	Peat charcoal, 85 per cent. carbon, dry	12,325	12·76
14	Tan, perfectly dry, 15 per cent. of ash...	6,100	6·31
15	Do. 30 per cent. moisture	4,284	4·44
16	Straw, 14¼ per cent. moisture, probably	7,600	7·87
17	Petroleum	20,240	20·33
18	Petroleum oils	27,531	28·50
19	Coal gas, mean of Ross and Harcourt...	34,292	35·50

357. Give the weight and specific gravity of some British coals.

Coals.	Cubic ft. in a ton.	Weight of one cubic foot.		Specific gravity
	Heaped	Solid	Heaped	
Welsh :—	Cubic feet.	Lb.	Lb.	Water = 1.
Anthracite	38·4	85·4	58·3	1·37
Porth Mawr (highest)	42·0	86·7	53·3	1·39
Llynvi (one of the lowest)	42·0	80·3	53·3	1·28
Average of 37 samples	42·7	82·3	53·1	1·315
Newcastle :—				
Hedley's Hartley (highest)	43·1	81·8	52·0	1·31
Original Hartley (one of the lowest)	45·6	78·0	49·1	1·25
Average of 18 samples	45·3	78·3	49·8	1·256
Derbyshire and Yorkshire :—				
Elsecar	47·4	80·8	47·2	1·296
Butterley	47·3	79·8	47·4	1·28
Staveley	44·9	79·8	49·9	1·27
Loscoe, soft	48·8	79·6	45·9	1·285
Average of 7 samples	47·4	79·6	45·9	1·292
Lancashire :—				
Laffack Rushy Park (highest) ...	42·6	84·1	52·6	1·35
Cannel, Wigan (lowest)	46·4	76·8	48·3	1·23
Average of 28 samples	45·2	79·4	49·7	1·273
Scotch :—				
Grangemouth (highest)	40·1	80·5	54·3	1·29
Wallsend (Elgin)	41·0	74·8	54·6	1·20
Average of 8 samples	42·0	78·6	50·0	1·259
Irish :—				
Slievardagh anthracite	35·7	99·6	62·8	1·59
Warlich's artificial fuel	32·4	72·2	69·6	1·15

358. Give the weight and specific gravity of some French coals and fuel.

Fuel in France.	Weight of one cubic foot.	Specific gravity.
	Lb.	Water = 1.
Pure graphite	145·3	2·33
Anthracite	83·5 to 91·0	1·34 to 1·46
Rich coal with a long flame	79·8 to 84·8	1·28 to 1·36
Dry coal with a long flame	84·8	1·36
Rich and hard coal	82·3	1·32
Smithy coal	79·8 to 81·1	1·28 to 1·30
Lignite	77·9 to 84·2	1·25 to 1·35
„ bituminous	72·3 to 74·8	1·16 to 1·20
„ imperfect	68·6 to 74·2	1·10 to 1·19
"Jeyet"	81·7	1·31
Bitumen, red	72·3	1·16
„ black	66·7	1·07
„ brown	51·7	0·83
Asphalte	66·1	1·06

359. How may pit-heaps or coal refuse be economically utilised?

Particulars of two attempts that had been made to deal with pit-heaps profitably were mentioned by Mr. J. Nasmith, at a meeting of the Manchester Association of Employers and Foremen. The first experiment was made at Seaton Burn, where a heap in the immediate neighbourhood of the village was causing great discomfort to the people. By covering it with sand, and withdrawing the gas by a blower through perforated pipes sunk to the depth of 6 ft. in the heap, the nuisance was entirely stopped, and a considerable recovery of ammoniacal liquor, with a small quantity of oil, was obtained. At Kelvinside, near Glasgow, a heap treated in the same way yielded ammoniacal liquor to the extent of several hundred gallons per day, the liquor containing five ounces of sulphate of ammonia per gallon. The patentee of this principle is Mr. L. H. Annom. In the treatment of heaps for this purpose, it was proposed to build them over culverts laid in the ground, and when the heap was complete and fired, the gas could be withdrawn through the permanent pipes.

360. In generating steam, which will give the best results per pound of slack used—wet or dry slack?

Dry slack will give better results than wet slack under the same conditions. From a series of tests made recently with much care, it appears that a mass of washed slack, holding 18 per cent. of water and 9·9 per cent. of ash, evaporated 5·7 lb. of water per pound of fuel; the same slack, with only 3 per cent. of water, made from 8 to 8·5 lb. of steam, showing a direct loss of 14 per cent. by using wet slack, after reducing to a standard of like qualities of coal free from moisture.

361. For the complete combustion of fuel, do you consider a fixed proportion of air necessary?

Yes; it has been proved by experiment that for the complete combustion of a fuel of a given constitution a fixed proportion of air is necessary. When combustion is complete, certain gases are obtained having a definite volume, an average specific heat and a fixed temperature, which is the maximum temperature which that fuel is capable of imparting. This assumes, of course, that no adventitious heat is added. If an excess of air be supplied, then that excess represents a useless volume through which the total heat must be distributed, with a consequent lowering of the temperature. If air be deficient, then the fuel will be imperfectly burned, producing carbonic oxide instead of carbonic acid, and yielding much less heat, with about the same volume of gas, and a consequent lower temperature. We approach the maximum temperature in proportion as we approach the proper proportions of air and fuel necessary to perfect combustion. In common grates exactitude in these proportions is widely departed from. At one time the grate is heaped with fresh fuel, giving off half-burned or wholly unburned gases; at another, with half-exhausted coals coated with ash, to which only a portion of the oxygen can obtain access. A stream of air, driven through a bed of ignited coals, first oxidises the lower layers, converting the carbon it touches into carbonic acid. This gas, rising through the coals, takes up more carbon, becoming carbonic oxide, which is, in part, re-oxidised above the coal, giving rise to flames. Unless there is a large excess of oxygen, some of the combustible elements of the gases will probably remain unconsumed, owing to imperfect intermixture, and a rapid cooling below the point necessary to ensure ignition by the nearly exhausted oxygen. If hydrogen be present in the form of hydrocarbon vapours it will, by its stronger affinity, seize on the oxygen to the exclusion of carbon, and may even decompose carbon already oxidised, this latter passing off in minute flakes, which form the dense black smoke always abundantly developed where bituminous or hydrocarbon fuels are burned with a deficiency of air. In furnaces these things are more or less modified by admitting a draught over the grate, but the loss of fuel is by no means wholly obviated.

362. Do you consider it advantageous to adopt smoke consumers for the complete combustion of smoke given off from the boiler fires?

Yes; and in large towns and thickly-populated districts it is compulsory to use means to lessen the emission of smoke from the chimneys or stacks. The best smoke consumer for economy that has come under the author's notice is one patented by Mr. D. H. Lowry, of Widnes, Lancashire, which may be seen at work on the inventor's premises. Perfect combustion of the smoke takes place after being converted into gas, whilst passing through and round the boiler. A very great heat is obtained with a very small expenditure of fuel, and the smoke given off is scarcely perceptible when once the furnace has attained the necessary heat. The cost of boiler and erection is, it is claimed, no more than that of an ordinary boiler, and the principle can be applied to all existing boilers at a small cost, no steam jets, patent doors or other appliances being required.

363. How is heat measured?

The heat required to raise the temperature of water 1 deg. Fahr. is called a unit of heat.

364. How many units of heat are there in one horse-power?

One unit of heat is equal to 772 foot-pounds. This fact was determined by Joule. Heat is produced by friction, and the friction that 772 foot-pounds is capable of producing will raise the temperature of a pound of water 1 deg. Since there are 33,000 foot-pounds in a horse-power, there are $\frac{33,000}{772} = 42{\cdot}75$ units of heat in a horse-power.

365. How many units of heat will raise the temperature of 1,000 cubic feet of air from 10 degs. to 60 degs.?

The specific heat of air is ·25. That is, if it requires one unit of heat to raise a pound of water 1 deg., it only requires ·25 or a quarter of a unit to raise the same amount of air 1 deg. 1,000 cubic feet of air at 10 degs. weigh about $\frac{39{\cdot}76}{459 + 10} \times 1,000 = 84{\cdot}8$ lb. To raise this amount of air from 10 degs. to 60 degs. would require $\frac{84{\cdot}8 + (60 - 10)}{4}$ = 1,070 units of heat.

366. What deleterious gases does a pound of coal produce in burning?

A pound of coal containing 90 per cent. of carbon will require about 10·5 lb. of air for perfect combustion. This will produce 11·4 lb. of carbonic acid. If air weighs ·08 lb. per cubic foot, carbonic acid will weigh ·12 lb. per cubic foot. Consequently a pound of coal will produce $\frac{11{\cdot}40}{{\cdot}12} =$

95 cubic feet of carbonic acid. If the coal is not perfectly consumed, but half the carbon is burned to carbonic oxide, we find the deleterious products to be 5·7 lb. of carbonic acid, and 3·07 lb. of carbonic oxide, equal to 47·5 cubic feet of carbonic acid and 40 cubic feet of carbonic oxide; a total of 87·5 cubic feet.

367. Do you know of any experiments to show the units of heat a pound of coal will give out in burning?

Yes. The following is from a paper read by Mr. William John Hudson, of the Woodside Ironworks, Dudley, before the South Staffordshire Institute of Iron and Steel Works Managers:—Experiment with Carter's patent tubular boiler, in which the fire is placed beneath the body, passes along the bottom, returning to the front by a set of 4 in. tubes, and again to the back by another set of 3 in. tubes, thus traversing the length of the boiler thrice. The temperature of the air as it left the boiler was 320 degs. In six hours 628 lb. of Duffryn Welsh coals evaporated 5,140 lb. of water at 52 degs. to steam at 212 degs., and we have therefore $\frac{(1,178 - 52) \times 5,140}{628} = 9,220$ units per pound of coal. A similar experiment was made with a Cornish boiler, the fire being inside as usual. In six hours 361 lb. of Duffryn coals evaporated 2,600 lb. of water at 53 degs. to steam at 212 degs., and we have therefore $\frac{(1,178 - 58) \times 2,600}{361} = 8,066$ units per pound of coal.

368. Are the actual and theoretic efficiency of coal the same?

Mr. C. M. Percy, in his *Mechanical Engineering of Collieries*, Vol. II., says:—"A pound of average coal developes, with perfect combustion, 12,000 units of heat, which, multiplied by 772, the mechanical equivalent in units of work of one unit of heat, equals 9,264,000 foot-pounds of work, representing barely a consumption of ¼ lb. of coal per indicated horse-power per hour. The very best engines of modern times, leaving out only a few exceptional cases, require not less than 2½ lb. of coal per horse-power per hour—showing a loss, in some form or another, of nine-tenths of the efficiency of the coal used for the generation of steam. The average colliery engine uses very much more than 2½ lb. of coal per horse-power per hour, consequently the loss of efficiency is very much greater."

369. Do all steam engines use the same gross quantity or weight of steam per unit of time, per horse-power of engine?

No; the useful power of a given quantity or weight of steam depends in a great measure upon the character, condition and perfection of the engine by which the steam is consumed. (1st.) The plain slide-valve engine, working with little or no expansion. (2nd.) The adjustable cut-off engine, working with a fixed ratio of expansion determined by the amount of work to be done, or by the fancy of the engineer. (3rd.) The automatic cut-off engine, in which the ratio of expansion is determined by the engine itself to exactly meet the requirements of load or work of the engine at any given instant of time. The economy in the use of steam in these different classes of engines is in the order named, the first being that of least economy, and the third that of the greatest economy. But there is also the condition of the engine to be taken into account. If there are losses from leaks at any point between the boiler and the working side of the piston of the engine, either from joints, valves, or piston, all such leaks militate against economy. There being therefore such great variations in the conditions under which the steam is consumed, evidently no one unit of horse-power per pound of steam consumed would be universally applicable.

370. Does covering the steam pipes with a non-conductor of heat effect any saving of fuel?

Yes, undoubtedly. Yet while this saving is admitted either tacitly or openly, too often it is looked upon as a small matter, and a somewhat doubtful expenditure. It is, however, a very important economy, and soon repays the small expense necessary.

371. Give the conducting powers of a few materials?

The experiment of Peclet gives the following as the conducting power per square foot of different materials, difference of temperature, 1 deg. Fahrenheit. Copper 1 in. thick, 515 heat units per hour. Iron, 1 in. thick, 233 heat units per hour. Ordinary plaster, 1 in. thick, 3·86 heat units per hour. Writing paper, 1 in. thick, ·346 of a heat unit per hour. Wool (any density), 1 in. thick, ·323 of a heat unit per hour. Blotting paper, 1 in. thick, ·274 of a heat unit per hour. These figures show that copper conducts 1,900 times as much heat as blotting paper, and 1,600 times as much as wool. Iron conducts 850 times as much as blotting paper, and 721 times as much as wool. These experiments show blotting paper to be the best known non-conductor of heat, with wool falling but a few degrees below.

372. What is the best non-conducting covering or felting that has come under your notice?

I have myself adopted the following non-conducting composition, which gives excellent results. It consists of paper dust from paper mills, better known in the mills by the name of devil-dust, and pure marl, the purer the better; the mixture is about three of marl to one of paper-dust put in a pug mill together and well pulverised. This covering can be applied to pipes of any diameter. Various coverings of asbestos and other non-conducting compositions are extensively advertised, and have been found to give good results in practice.

* * *

CHAPTER VIII.

PRACTICAL MINING RELATING TO UNDERGROUND WORKINGS.

373. What is the first thing to be decided after the shaft is sunk?

After the coal is reached the first thing to be decided is the course and number of headings or straight places. The direction can be decided by the dip and rise of the coal, the position of any large faults, and the nature of the boundary.

374. Give the number and sizes of shaft pillars for various depths.

The shaft pillars should be cut round; their size should not be less than 40 yards square, and the deeper the pit the larger they should be. Supposing the minimum be 40 yards for a depth of 60 fathoms, 10 yards should be added for every 20 fathoms, so that at a depth of

80	fathoms	the shaft pillars	would be	50	yards square.
100	„	„	„	60	„
120	„	„	„	70	„
160	„	„	„	90	„
200	„	„	„	110	„

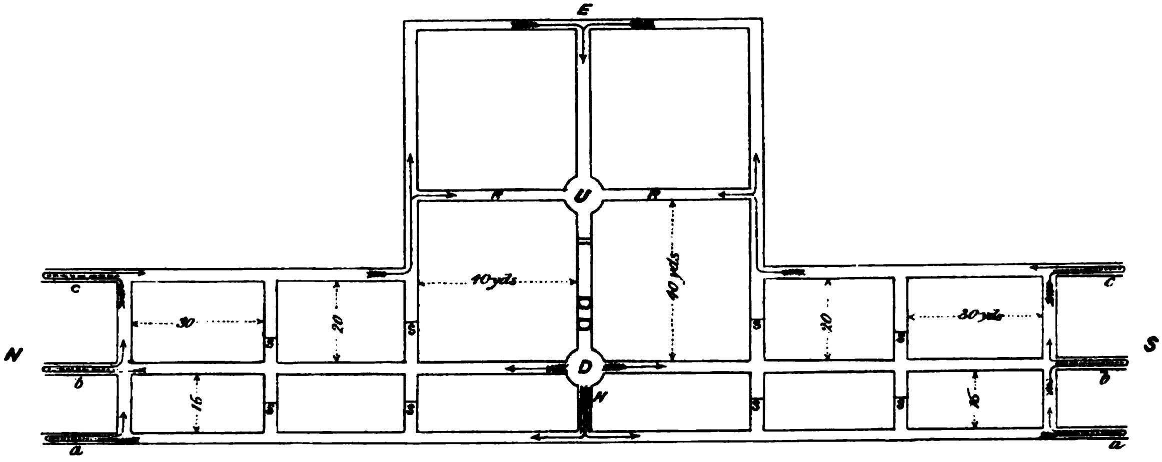
375. What are the next steps to be taken after the shaft pillars are formed?

The making of mouthings and the driving of levels or narrow works; this is mostly set down as dead work. The excavations, which constitute the dead or narrow work, consist of drifts, headings or roadways, called way-gates, gate-roads, water-gates and levels, driven through the mass of coal left to support the sides of the shaft, and called, on that account, shaft pillars, or high pillars. These levels are the principal roadways, air-end ways, and water or lodge levels of the mine. The roadway is the main horse-road through which all the produce of the mine will have to be conveyed to the pit bottom, and the air-end way is chiefly employed for the return air when it has passed through all the workings, which are separated from the roadway by a barrier or pillar of coal 20 yards thick on the higher side of the roadway, measuring crop and dip; this barrier is cut through at intervals of every 30 yards, these passages are termed openings, and are for allowing the air to pass from one level to the other or from the intake to the return. As each opening is cut, the last one is built up with bricks and mortar. The lodge or water levels are to provide a main for all the water the mine makes to flow through to the sump or lodgment.

376. If the strata are highly inclined, the tendency of the pillars to yield is greater than when the strata are horizontal. Can you give any method to determine the size of the shaft pillars under these circumstances?

No; the difficulty of preserving the shaft through steep measures is in some districts often found to be a very serious one. The strength of the coal will also materially affect the resistance of the pillars, but the difference in the strength of coal is not so important a factor as the nature of roof or floor of the coal seam. When the floor consists of soft underclay, the pressure of the pillars tends to force it to rise in the roadways between the pillars. This tendency of the floor to rise between the pillars is often very troublesome in the workings, when

Fig. 49.



it is known as the "creep." The only way to counteract this tendency is to increase the dimensions of the pillars. The amount of increase demanded by each of these conditions cannot be stated in a general manner.

377. In seams of a high inclination, is it necessary to leave a greater shaft pillar on the rise side of the shaft than on the dip side?

In inclined seams it is necessary to leave a greater shaft pillar on the rise side of the shaft than on the dip side. Rocks necessarily break at right angles to the line of stratification, consequently the line of subsidence does not proceed in vertical lines from the excavation, but at right angles to plane of beds. In Silesia experiments have proved that the direction of subsidence is at an angle of about 70 degs. from the plane of bedding. The above is the opinion of Mr. H. W. Hughes.

378. By what methods are coal seams generally worked?

All coal seams are worked either by pillar-and-stall or longwall, or by some modification of these methods.

379. Give a sketch of the opening out of a seam of coal on the pillar-and-stall method?

The relation of the levels to the shafts and the coal to be wrought, in position and direction, will be understood by referring to the plan shown in fig. 49. This plan represents the method of laying out the workings generally followed in Lancashire. The direction of the dip of the seam is from U to D; thus D is the deeper shaft, being the downcast, and U the upcast, being the one on the rise. When these shafts are carried down to the required depth, the first step is to connect them by headways driven through the coal. This connection will provide for the ventilation by enabling each shaft to serve the purpose for which it is ultimately intended. The current of air will descend through the downcast, D, and ascend through the upcast, U. It now remains to set off the levels at right angles to the direction of the dip of the seam, as seen at *a a*, this is the water or lodge level; *b b* are the roadways through which the produce of the mine has to pass along from the workings to the shaft; *c c* is the air-end way or return airway. As these levels are driven exactly alike on both sides of the shaft, it will be sufficient to describe those on the one side only. Before going into any description of these levels, however, we may state that it is not always requisite in small collieries to have three levels. In such a case the lodge level is not driven—only the roadways and air-end ways; but for extensive collieries a third level is usually added, to obtain a more effective ventilation. Sometimes the shafts are sunk closer than those we have chosen for illustration, as will be seen in fig. 50. It will be seen in this plan that the levels are the same distance from each other as in fig. 49. In driving the levels out from the shafts, care must be taken, as before remarked, not to have the shaft pillars too small. When the seam makes little or no water, the lodge level is not driven on the dip side of the shaft, but started along the roadway at about 40 yards distance, in a slantwise direction, until there is a sufficient thickness of coal to form a barrier between the two levels. Referring to plan, fig. 49, the opening which connects the two shafts with each other will require either to have a permanent stopping put in, or a pair of double doors, as shown on plan, or the whole current of air will flow direct from pit to pit, instead of circulating through the workings. The permanent stopping is preferable unless the headway is wanted for passing and repassing to each pit, when the two doors will be required. With respect to the ventilation, on the accompanying plan the

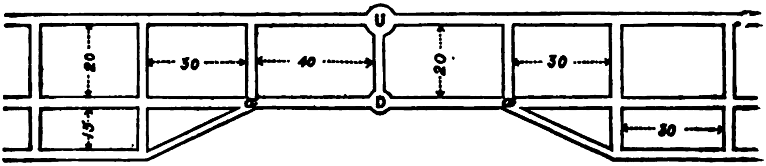


Fig. 50.

CALIFORNIA

arrows show the direction of the current of air; the dotted lines at *b c*, where brattice cloth will be required to carry air past the openings to the working face; at R R regulators will be required to allow only a certain portion of the air to go through these channels, and the larger bulk to return from the rise district; the dotted lines at the doors, D D, indicate the way they open and shut. The student, when marking a plan for ventilation, should always make the circular part or bow of the D face the current. All openings marked S will require stoppings in them, which are usually built with bricks and mortar.

380. What principally decides the size and form of the roadways?

The dimensions of the roadways will be regulated by three things, viz., the thickness of the seam through which the levels are to be driven, the strength of the roof, and the requirements of the system of transport adopted in the mine.

381. How is the roof near the pit-bottom or pit-eye supported?

Generally either by timber or brickwork. Where timber is used it will be well to wall the sides with bricks; but a brick arch is preferable, and if the floor is weak the walling should rest on an invert. As here are the main outlets of the mine, which moreover constitute the air channels through which the workings will be ventilated, the greatest attention should be given to their design and construction so that they are as convenient and durable as possible. A good design for these roads will very materially influence the quantity of the output and the cost per ton, whereas any weak places left untimbered or unbricked may result in disastrous accidents through the falling-in of the roof and consequent blocking of the roadway.

382. When the roof is secured with an arch of brickwork, can you give a rule for finding the cost of labour for putting in the brickwork?

Yes, as already stated in the chapter on "Tunnel-driving," the usual cost for putting in an elliptical arch of brickwork, 9 in. thick per lineal yard, is 1s. 6d. for every foot the arch is in diameter; that is, for an arch 8 ft. in diameter, the price will be 12s. per lineal yard; if 6 ft. in diameter, 9s. per lineal yard; or if 10 ft. in diameter the price would be 15s. per yard; there being an increase or decrease of 1s. 6d. per yard for every foot the arch increases or decreases in diameter; as the thickness of the brickwork increases or decreases, 6d. must be added to or taken from the cost for every foot the arch is in diameter, and for every 4½ in. thickness the brickwork increases or decreases. So that if the brickwork is 14½ in. thick, the price for every foot the arch is in diameter will be 2s., if 18 in. thick it will be 2s. 6d., and so on in arithmetical progression. At the above prices the bricks and mortar and all necessary materials have to be placed conveniently at hand, but the contractor is to find all his own labour and tools, and pack tight the hollow space between the arching and rock with very fine *débris*; any arching done at surface which requires no packing will be a little less in cost.

383. Give a formula for working out the cost of putting in arching?

A good formula for finding the cost of putting in arching under ordinary circumstances has already been given in question 205.—Let D denote the diameter of arch in feet, L denote length of arch in yards, and P the price to be paid in pence for every foot the arch is in diameter. Thus $\frac{D \times L \times P}{240}$ = total cost of arching in pounds per lineal yard. For example, we will suppose an arch to be 10 ft. in diameter and 18 in. thickness of brickwork and 50 yards in length, then the cost would be by formula—

$$\frac{\overset{D}{10} \times \overset{L}{50} \times \overset{P}{30}}{240} = £62\ 10s.$$

The following table gives the cost of a single yard of arching of different thicknesses and diameters worked out by the above formula:—

Diameter in feet.	Thickness, 4½ inches.			Thickness, 9 inches.			Thickness, 18½ inches.			Thickness, 18 inches.		
	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.
2	0	2	0	0	3	0	0	4	0	0	5	0
3	0	3	0	0	4	6	0	6	0	0	7	6
4	0	4	0	0	6	0	0	8	0	0	10	0
5	0	5	0	0	7	6	0	10	0	0	12	6
6	0	6	0	0	9	0	0	12	0	0	15	0
7	0	7	0	0	10	6	0	14	0	0	17	6
8	0	8	0	0	12	0	0	16	0	1	0	0
9	0	9	0	0	13	6	0	18	0	1	2	6
10	0	10	0	0	15	0	1	0	0	1	5	0
11	0	11	0	0	16	6	1	2	0	1	7	6
12	0	12	0	0	18	0	1	4	0	1	10	0
13	0	13	0	0	19	6	1	6	0	1	12	6
14	0	14	0	1	1	0	1	8	0	1	15	0
15	0	15	0	1	2	6	1	10	0	1	17	6
16	0	16	0	1	4	0	1	12	0	2	0	0
17	0	17	0	1	5	6	1	14	0	2	2	6
18	0	18	0	1	7	0	1	16	0	2	5	0
19	0	19	0	1	8	6	1	18	0	2	7	6
20	1	0	0	1	10	0	2	0	0	2	10	0

384. By what is the width of the roadways usually regulated?

The width of the roadways is determined by the strength of the roof. Whether the roof be taken down or the floor removed should be regulated by the following considerations:—If there is a strong roof the underclay or floor should be taken up; on the other hand, if the floor is strong and the roof weak and tender, the roof should be taken down; if the floor and roof are both strong or both of a tender nature, one of them may be a good material for brickmaking—either firebrick or other description—and then whichever is the more suitable for that purpose should be removed.

385. Why should the pit-bottom or pit-eye be larger than any other part of the roadways?

It is scarcely possible to allow too much room for loaded and empty tubs to stand, and men and horses to pass and repass at the pit-bottom. Want of room here is a great impediment to all underground arrangements.

386. Give a short table showing the crushing resistance of the strata overlying the seams of coal at various depths.

The strata overlying the coal measures consist chiefly of shales, clays and sandstones. Taking the average specific gravity of these as—say, 2·3, we have at a rough average 150 lb. as the weight per cubic foot of the strata overlying a seam of coal. The following table will then give the weight or pressure of the superincumbent strata for various depths:—

Depth.	Pressure per square foot.	Pressure per square inch.	Equal to the resistance to crushing of
Yards.	Tons.	Lb.	
700	140·7	2,184	weak sandstone.
800	160·8	2,498	
900	180·9	2,808	
1,000	201·0	3,120	ordinary sandstone.
1,500	301·5	4,680	limestone.

Of course the above table does not indicate that a bed of sandstone at a depth of 1,000 yards would be crushed to powder, but that a block of sandstone free on its sides, if subjected to a pressure of about 3,120 lb. per square inch of area, would be crushed.

387. With roof and floor sufficiently strong, what width would you prefer to have your main horse roads, and why?

Generally, the width which is best adapted to meet all requirements is from 8 ft. to 9 ft. This will give sufficient width for a double line of tram-rails, allowing a train of empty tubs to be going in-bye while a train of loaded tubs is coming out-bye. A gross mistake is made by some colliery managers and proprietors who think they are getting their work done more economically by reducing the sectional area of the levels to their lowest possible limit. To assume that the cost of driving a level diminishes as its sectional area is an error. We may take the two following instances for example:—Suppose one level to be 5 ft. by 9 ft., and the other 5 ft. by 5 ft., in both cases the miner being paid 1s. per ton for his coal, and so much per yard. In the former case in driving 1 yard in the level there would be 5 cubic yards of coal; and reckoning each cubic yard of coal to weigh 19 cwt., there would be 4 tons 15 cwt. of coal at 1s. per ton, which would amount to 4s. 9d.; and suppose the collier received 2s. 6d. per yard for coal and yardage, this would amount to 7s. 3d. for each yard of driving. In the latter case there would be in 1 yard of driving, 2·77 cubic yards of coal; reckoning 2 tons 13 cwt., at 1s. per ton, would amount to 2s. 8d., and to make the collier's 7s. 3d. for coal and yardage, he would require 4s. 7d. for each yard of driving, where in the former case it was only 2s. 6d.; this would leave a balance against the proprietors of 2s. 1d. I have known instances where colliers have been receiving 5s. per yard for a level 5 ft. wide, and so much per ton for their coals, and where, in the same seam of coal, the same men have driven levels or "breastings" 15 ft. wide at 2s. 6d. per yard, with the same price per ton for coal, and have made better wages, although in this case they have had a considerable amount of packing to do on the lower side of the level.

388. If you have a thin seam of coal to work, why would you take down the roof or take up the floor to make a good-sized pony road?

In some collieries where the seams are thin, the overman or underlooker appears to be content to have a road just large enough for the tub to pass to and fro, and when horses are used, the smallest possible being secured; so also with the airways—some are content if a man can pass through them on hands and knees. It is the opinion of the author, however, that if a seam of coal will pay to work with small ponies and low bad roads and airways it will certainly pay much better to have larger ponies and good roads and airways. A boy can then drive a pony and eight or ten tubs with greater ease than with one or two tubs in a bad road.

389. As the form and shape of a tub materially affects the output of coal, can you give a description, with sketches, of a good tub to carry, say, 10 cwt.

When it is possible, the tub should be made 12 in. longer than it is wide, with steel wheels fast on the axles and of as large diameter as can be conveniently run on round top rails, so as to minimise the resistance and friction. The friction of tubs shows when tested one-68th as the average co-efficient with a gross average load of 1,033 lb.; a co-efficient of one-70th for a load of 607 lb.; of one-88th for a load of 351 lb., and a co-efficient of one-59th for a load of 265 lb., and this variation, although the same road was used for all the experiments, and all the wheels and axles

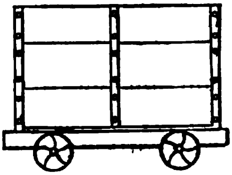


Fig. 51.

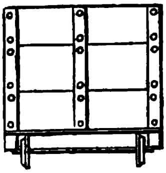


Fig. 52.

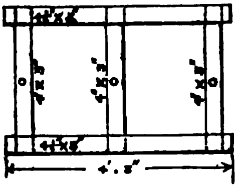


Fig. 53.

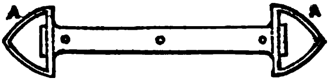


Fig. 54.

were uniform in dimensions. Figs. 51 and 52 are side and end views of a tub, the body being 4 ft. 2 in. in length and 3 ft. 2 in. in width, having a steel plate bottom $\frac{3}{16}$ in. thick × 3 ft. 2 in. × 4 ft. 2 in. The frame of the tub (fig. 53), is made of oak, the side pieces are 4½ × 3 in.; the slots are 4 × 3 in.; the draw-bar (fig. 54), is made of iron 2½ × ½ in., the ends of the draw-bar where the rings pass through are made of iron 2½ × ⅝ in., these being the points which will have to bear the greatest strain. The rings A are made V-shaped and forged out of 1 in. round iron. The above draw-bar is suitable for large gangs or journeys that have to be drawn up inclines at a high gradient.

390. At what inclination should a main horse road be driven, and for what reason?

The main horse roads should be driven with a slight inclination towards the shaft, so that the water may flow from the workings to the bottom of the shaft whence it has to be raised; there should also be as little resistance as possible to the train of loaded tubs coming out from the workings towards the shaft. This necessitates driving the level in a slightly ascending direction from the shaft, and it is a matter of great importance, since by adapting the fall of the road for the loaded trams, a large saving of labour will be effected, whether horse or other power be employed. Numerous experiments have proved that an incline of 1 in 130, or a little more than a quarter of an inch in the yard, gives the maximum of advantageous effect in drawing the loaded tubs towards the shaft and the empty ones back by horse-power, and when practicable this inclination should be adopted.

391. What means would you adopt to drive a level straight or with a given bearing?

This end is attained by fixing points, first determined by the use of the dial or theodolite, and afterwards preserved by fixed points, consisting of two plumb lines suspended from the roof of the heading, in such a position that a straight line passes through them in the same horizontal plane. These lines will indicate the direction in which the level has to be driven, and they should be placed from 10 to 20 yards apart—the greater the distance the more accurate the work will be. After these lines or points have been fixed up by the manager or surveyor, the man in charge of the working-place should be responsible for them, and the keeping of the level in its proper bearing.

392. When driving levels, how would you check the inclination, that they do not rise too fast?

As before stated, levels should be driven with an upward inclination of a quarter of an inch to the yard, and care must be taken that they do not exceed this inclination, as there is always a tendency to rise too fast. Different kinds of instruments and methods are adopted for checking the inclination of levels when driving, which are simple, both in construction and in use. The following is a description of one of the most suitable for the purpose that has come under the author's notice. It is termed a plumb-bob, and in addition to the plumb-bob there is a small spirit level fixed to it, as shown at A, fig. 55. It will be impossible to make a mistake with this instrument, the plumb-bob and spirit level acting as a check the one upon the other. It is commonly made out of deal boards 1¼ in. thick; the foot-piece, B, being 6 ft. in length, and 4½ in. broad; the centre or vertical piece is 3 ft. in length and at

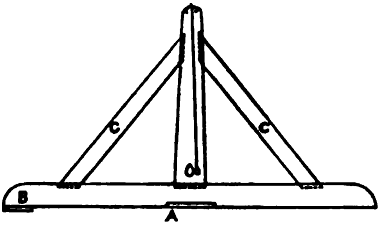


Fig. 55.

the lower end it is 6 in. broad, tapering to the top end until it is only 4 in. The stay pieces, *c c*, are 3 in. broad, and are tenoned into each other, as shown by the dotted lines. At the one end a piece of board ½ in. thick is screwed to the foot, so as to give the level its right inclination, and when used, it is laid on the tram rails, the end B being farthest from the face. If the level is being driven at the right inclination the spirit level will set in its ordinary course—that is, it will lie in the centre of the glass tube, and the plumb-bob will hang in the centre of the hole made in the T-square.

393. What method would you adopt, in driving a tunnel dipping 1 in 5, to check the inclination, supposing the tunnel to be going through he measures from one seam to another?

To check the inclination of a tunnel or other road-way with an inclination of 1 in 5 from end to end, I would use

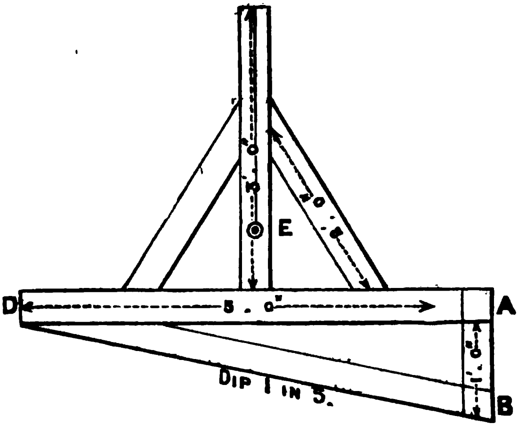


Fig. 56.

an instrument similar to fig. 56, which is one of the author's introduction. It is similar in construction to fig. 55, except that there are two sole-pieces, A and B. The bottom of the sole-piece B is one foot apart from the bottom of the sole piece A; at the other end of the instrument, D, the bottom sole-piece is brought to a feather edge, thus forming a dip of 1 in 5 from D to B. If the sole-piece B is placed on the rails the plumb-bob, E, should hang in the centre of the hole made for it, if the tunnel or roadway is being driven with its proper dip.

394. Describe the method of ventilating levels in process of driving.

Brick and mortar stoppings are built in the openings or cut-throughs, as shown at *s s*, fig. 49. If the seam gives off much gas, so that it is impossible to drive the levels 30 yards from cut-through to cut-through, the distance may be reduced to 20 yards. It is undesirable to cut through at too frequent intervals, and this is obviated by the use of brattice, which is fixed longitudinally, dividing the level into two portions from the last cut-through to the working face (as shown by dotted line at *a b c* on plan), allowing the air to pass on the one side to the working-place and return on the other, as shown by the arrows. The bratticing usually consists of wood or canvas, but generally of the latter material.

395. Describe how you would fix up brattice cloth.

The usual way of fixing brattice cloth is to set props in the middle, or nearly so, of the heading, at about every 9 ft. apart. Long strips of wood called brattice staffs, 3 in. broad and 1 in. thick, are placed over the props; the props are then driven up under them very tight against the roof, and the brattice cloth is secured to the staffs by small nails.

396. When roadways require timbering, what kind would you put in them—and why?

There are several kinds of timber used in securing roadways, but I would recommend larch, owing to its elasticity or toughness, for as well as a vertical pressure there is a side weight, and on this account larch is preferable, as its elasticity will allow it to give or bend before breaking. For the last twelve months we have been supporting the underground roadways at the Aldridge Collieries with steel girders instead of timber; a section of the girder is shown in fig. 57. The first cost is about twice that of timber, but the durability of a steel girder will probably be ten times that of timber. The girders put in at the Aldridge Colliery look as sound after twelve months' wear as when first put in, although they are mostly in roadways of 10 ft. span with a very heavy roof. Should the girders at any time become bent under the pressure of the roof, they can be taken out, reversed, and re-set. The girders are much handier for the men to use than timber, make a neater roadway, being more uniform, and allow at least 6 in. more height in the roadways—a great consideration at a large colliery. Even when completely worn out the girders will sell for four times as much as old timber. The necessary strength or section of girder will depend chiefly upon the width of the roadway; for a roadway 12 ft. wide, the girder required would be about 6½ in. deep with 5 in. flanges top and bottom; this would weigh about 33 lb. per foot. For a roadway 10 ft. wide, the girder would be about 6 in. deep with 4½ in. flanges, and would weigh about 27 lb. per foot. Roadways of less width would require girders of proportionately less section. For roadways of from 6 ft. to 7 ft. wide, old railway metals may be used to support the roof, and after being in use for some years for this purpose will be worth as much when taken out as when first put in. It is the author's experience that where the roof of the roadway is wet, and in return airways, timber supports frequently require renewal, but steel girders entirely overcome this difficulty.*

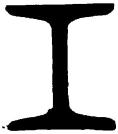


Fig. 57.

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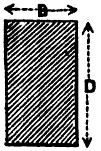
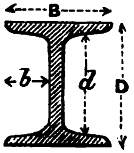
* **Rule for finding the breaking weight of beams and girders:—**
W = Breaking weight in cwts.



$$\left.\begin{array}{l} B = \text{Breadth} \\ b = \;,, \\ D = \text{Depth} \\ d = \;,, \end{array}\right\}\text{ in inches.}$$



397. Can you give the comparative crushing strengths of some kinds of timber used in and about mines?

Taking English oak at 4,074; larch 3,800; ash, 3,572; elm, 3,469; beech, 3,079; spruce, 2,522; yellow pine, 2,193.

398. The question of timbering underground workings is receiving great attention from persons interested in mining. Will you give a few practical remarks thereon?

The weight of the overlying strata exerts a most powerful crushing pressure, and no better method of resisting this pressure is known than an efficient system of timbering and packing. The cost of timbering demands that there shall be as little waste as possible, and the safety of the workmen requires that the system adopted shall be efficient. To determine the limit of safety and economy in timbering under all circumstances will task the ingenuity and knowledge of the most skilful manager. In the present state of mining, economy is essential, and in no branch of mining is a saving more likely to be effected than by an intelligent system of timbering and packing. A knowledge of the fractures of the rock forming the roof of a mine tells the experienced miner where props are required and where not. It should be remembered that there is no true economy in the use of inferior timber because of its cheapness, nor in unduly limiting the supply. A great deal depends upon

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L = Length in feet between supports.

C = Weight in cwts. required to break a bar 1 in. square and 1 ft. long—loaded in the middle.

$2C$ = Weight in cwts. required to break a bar 1 in. square and 1 ft. long—load equally distributed.

For solid beams $W = C\frac{B\,D^2}{L}$, loaded in centre

„ $W = 2C\frac{B\,D^2}{L}$, load equally distributed.

For girders $W = C\,\frac{B\,D^2 - 2\,b\,d^2}{L}$, loaded in centre.

„ $W = 2C\,\frac{B\,D^2 - 2\,b\,d^2}{L}$ load equally distributed.

Values for C = 28 steel, 22 wrought iron, 4 fir.

the intelligence and judgment of the workman as to where timber should be used. In some cases, as stated in a former question, brick or stone arching is put in the main roads leading to the pit-bottom, and in the long run is the most economical. Sometimes, in working on the long-wall system, pieces of timber 2 ft. to 3 ft. long placed across each other by twos, and set up in double rows at convenient distances apart (see fig. 58), may be used, and a marked economy effected over single props, as most of these pieces of timber (called chocks), can be recovered from the goaf. Much of the useful effect of single props is lost by failing to place them in a line with the direction of the pressure. This is a most important point in timbering, and should always be kept in view. Timbering is a most important subject, but the conditions are so various in different mines that it is impossible in this work to exhaust the subject; indeed, to do so would require a volume to itself. A thorough knowledge of timbering can only be attained by years of experience, careful observation and study. The author is of opinion that practical mining in general has suffered from the restrictions as to the age at which young persons may enter the mine, by which they are deprived of three or four years of useful mining experience, as compared with former times. In former years, we found boys in the mines doing boys' work, which nowadays men are

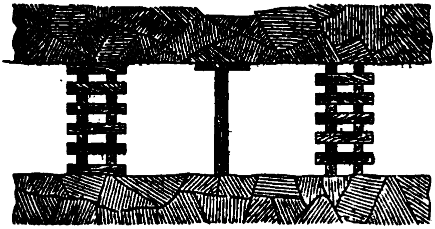

Fig. 58.

doing not so skilfully and in many cases showing a lack of intelligence, which earlier youthful experience would have given.

399. Do you consider that falls of roof and sides are in any way accounted for by the action of the atmosphere?

Yes, in shallow mines; and, especially in summer, when the atmosphere is heavily charged with moisture. This will be readily understood by those familiar with the working of the ironstone mines of South Staffordshire, where it is a common practice to throw water on the working face; the water causes the working face to crack and smoulder and thereby dispenses with holing, and in a very short time it can be pulled or rated. In the same way atmospheric vapour will act upon underground workings, the vapour being condensed on coming in contact with any strata colder than the air. As above stated, this action will be greater in shallow mines and in the summer months, for the reason that strata in shallow mines are much colder than in deep mines, and the great amount of vapour contained in the atmosphere in summer will be more readily condensed.

400. Many mining engineers say that falls of roof are more frequent during the night than in the day. Is there any reason for this?

I consider this to be so, and as before stated, more in shallow mines and in summer months. I expressed my views in a paper read in the year 1878 before the South Staffordshire Institute of Mining and Mechanical Engineers, which will be found in Vol. IV. of their *Proceedings*, and also in a paper read before the North Staffordshire Institute of Mining and Mechanical Engineers some four years earlier. My theory is that a certain amount of heat is absorbed by the earth every day, more naturally in the summer than in the winter months. This heat is given off again by radiation during the night, else the temperature at the earth's surface would soon become so great that nothing could live upon it. This will readily be understood by observing a grass field, which on the morning following a very warm day will appear as though a heavy shower had fallen upon it; it, however, is simply the watery vapour condensed from the atmosphere during the night. Exactly in the same way the watery vapour is condensed from the atmosphere of mines on to the roof and sides of the roadways (especially in shallow mines and in roadways near the pit bottom), as the air flows through them. It has but little effect upon the unbroken or solid mass of strata, the temperature of which is maintained by its inner sources of heat, but any broken or fractured parts of the roof or sides will soon fall to a low temperature, as being separated from the solid mass, the capacity for storing heat in these cases is not so great. The air, consequently, deposits its excess of moisture upon these cold and broken surfaces, exactly as steam from a boiler is condensed when it comes in contact with any cold substance.

401. What are the pieces of timber used in securing the roof and sides of the roadways called?

Different terms are used in different districts. By some they are termed "couplings," "settings," "caps and props," "bars and legs," but in most districts they are termed "props" and "bars."

402. If the sides of the roadway are strong, and the roof only weak, how would you support the roof?

By placing pieces of timber, termed bar-rests (let into the coal or rock), upon each side.

403. If one side only of the roadway needs supporting as well as the roof, in what manner would you fix your timber?

In this case the timber may be put in as shown in fig. 59. A hole is cut in the side of the coal or rock at A, to receive one end of the bar, a short hole is also cut in the floor at B, to receive the lower end of the prop; the prop is then placed under the bar and driven to its vertical position; or, if the roof is very soft and fallen, the prop is placed in an upright position and the whole structure tightened by means of wedges, &c.

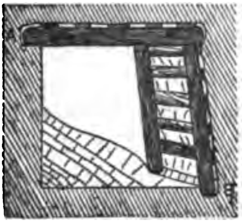

Fig. 59.

404. Describe the manner of putting in timber when the sides and roof of the roadway need supporting.

In this case the mode of fixing in timber is as shown in fig. 60. The two side props are slightly inclined towards the axis of the roadway, surmounted by a bar and securely held together by brackets, as shown at A A; one advantage of the inclination of the props is to reduce the length of the bar. When the floor is soft a piece of timber is sometimes

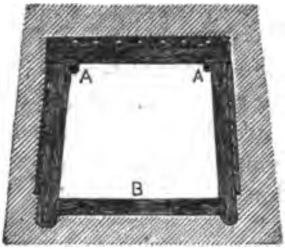

Fig. 60.

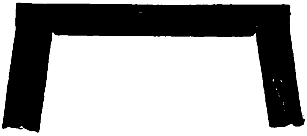

Fig. 61.

placed in at the lower ends of the props, as shown at B, to prevent the props from being pushed out of their places In some instances the colliers or timbermen "nip" or cut grooves at the ends of the bars, as shown in fig. 61, but as this process weakens the bar very considerably it should be avoided, and brackets used as shown in fig. 60.

405. Where the roadways are of extra width to provide shunt pass-byes, &c., in what manner would you put in timber to support the roof?

When two or three lines of tram-rails are required, the timber supporting the roof is usually arranged as shown in figs. 62 and 63. The main object in this system is to support the bar A and divide the bearing. The pieces of timber marked C D E are called stanchions, and are placed under the bars, as seen in the illustrations. Sometimes places are made in the sides of the props for the stanchions to rest in, as seen at H H, fig. 63.

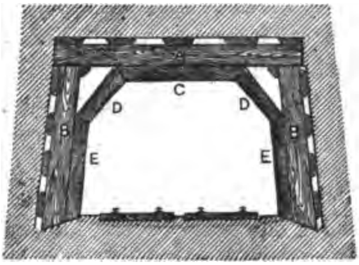

Fig. 62.

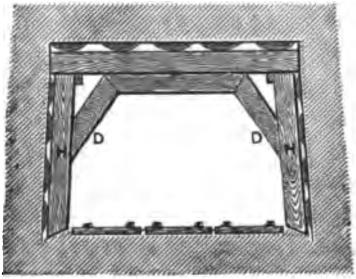

Fig. 63.

406. Under what conditions is the longwall system of working advantageous?

The following are the general conditions which should obtain where the longwall system is adopted:—A seam free from faults; a thin seam; a seam with a dirt parting; a seam with ironstone working with the coal.

407. What is meant by longwall?

It is a system of working all the coal away at once, leaving no pillars.

408. What are the advantages of the longwall system?

In longwall 14 per cent. more large coal is obtained than in pillar-and-stall, and 15 to 25 per cent. more coal per acre. The system is simple, ventilation more easy, and the men work with greater safety.

409. Where is the system of longwall mostly adopted?

In Shropshire, Staffordshire, Derbyshire, and Leicestershire.

410. How is the direction of the face determined when it is decided to work the seam by the longwall system?

The proper position of the wall face depends chiefly upon the inclination of the seam. If the inclination is moderate the wall face should be at right angles to the dip of the seam; in this case the roads are easy to maintain. If the dip of a seam is considerable, it is advisable to have the wall face parallel to the direction of the dip. In this case the coal will be chiefly transported by cross-cuts, worked, perhaps, as self-acting inclines. With a crushing roof the wall face should, if possible, be at right angles to the cleat; with a strong seam the wall face should be parallel to the cleat.

411. Is there anything else that has come under your notice favouring the longwall system in preference to pillar-and-stall?

The following are a few of the principal points in favour of the longwall system:—In the first instance we will suppose fig. 64 to be an area of coal to be worked out on the pillar system (as it is usually carried out in the county of

Lancashire), and to measure 110 yards by 120, which would give a total area of 13,200 yards. We will also suppose that the area of the coal is formed into blocks or pillars, as seen at B on plan. When these pillars have to be worked away, each pillar has to be split by two horizontal levels driven through it, termed by the miners "splittings," as seen at E. The total yardage paid to the colliers in this area, working on the pillar system, would be 2,250 yards, as in the whole area measuring from A to C there would be fifteen levels driven 110 yards each, and measuring from A to B there would be five openings or cross-cuts 120 yards eac and supposing each collier to be paid 2s. 7d. for every yard of driving in the straight work, the total cost for yardage in the above area would amount to £290 12s. 6d. It is customary also for the colliers to receive 6d. per yard when the pillars are being worked back from A to C, and this on the fifteen levels, 110 yards long, would increase the cost by £41 5s., giving the total cost for yardage in the whole area £331 17s. 6d., which would amount to nearly 3½d. per ton, supposing there are 23,100

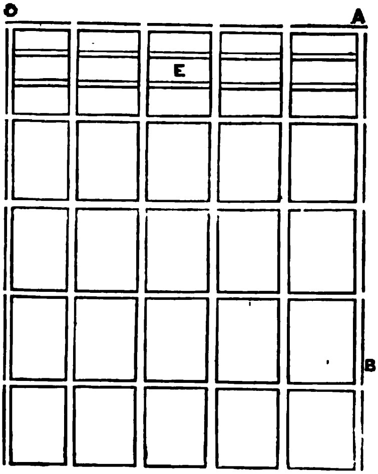

Fig. 64.

tons of coal in above area, which will be about the maximum quantity with a seam 6 ft. in thickness; if, however, the seam is thinner, the cost per ton for yardage will be more, the difference being in favour of longwall work, by which system also a larger proportion of round coal, and a larger tonnage per acre will be extracted. There are other points in favour of the longwall system. For example, when the seam is worked by the pillar system a great quantity of brattice cloth or canvas is required to convey the ventilation directly to the working faces, and a large number of tram rails and sleepers are required in the many excavations; and it often happens that a great number of the sleepers and occasionally rails are buried and lost through sudden falls of roof when the pillars are being extracted; on the other hand, when working by longwall a large proportion of the above material is not required, and this effects a great saving in cost. For these and many other reasons the longwall system is recommended.

412. Give a sketch of the roadways, &c., when working a seam of coal by longwall, free from faults, and inclination moderate.

If the seam of coal is level or nearly so, and the roof favourable for longwall, the headings should be driven to form the shaft pillars, the coal being then worked away in every direction, and roadways carried through the goaf as shown by dotted lines, fig. 65. The main roadways, marked A A A A, are carried direct from the shaft, other roadways being started out of these at intervals of 60 or 80 yards, according to circumstances, which divide the wall face into equal distances. To give a sufficient height in the roadways, the roof is taken down and the loose *débris* stowed on each side of the roadways to form pack walls, as shown at B in sketch.

413. How would you timber and pack your wall face under various conditions?

In some cases after the coal is brought down it is found necessary, where the roof is very tender, to insert what are termed wall bars, which chiefly consist of prop timber of 3 in. or 4 in. diameter, and are made flat, to fix against the roof. Two parallel rows of props are fixed along the wall face, and in some instances three. When there is not sufficient material to pack the roof tight along the wall face, then open wastes are left, as shown in fig. 66. It will be seen by referring to the plan, that one row of props is fixed along the face as close to the coal as possible, the roof always having a tendency to break along the line of face; another row of props is fixed along the front of the pack walls, and a third row is fixed in the wastes to prevent the roof from breaking too near the face. In extreme cases, where the roof is very weak, grooves are cut in the face of coal to the depth of the holing; in these props are set, as shown at A A A on plan, to support the roof while the collier fixes his wall-bars. These wall-bars are, as before stated, thin poles about 5 ft. in length and from

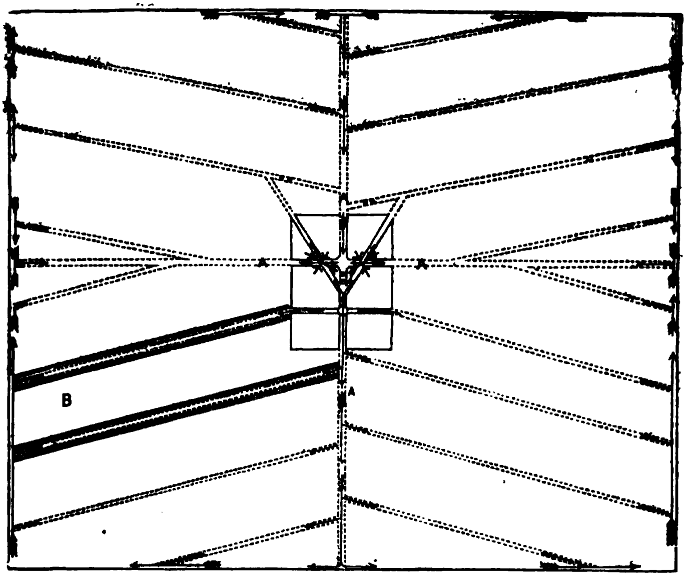

Fig. 65.

2 in. to 4 in. diameter, and are used along the working face to support the roof where it is tender. They are sometimes fixed with a prop under each end, and sometimes with a prop under one end only, the other being inserted in a hole made in the coal-face. From the author's experience, however, he considers small steel girders much cheaper and safer than the timber bars above referred to. Girders for this kind of work need not be above 7 lb. weight per foot. The author is of opinion that colliery managers ought to give special attention to the substitution of steel for timber in underground workings.

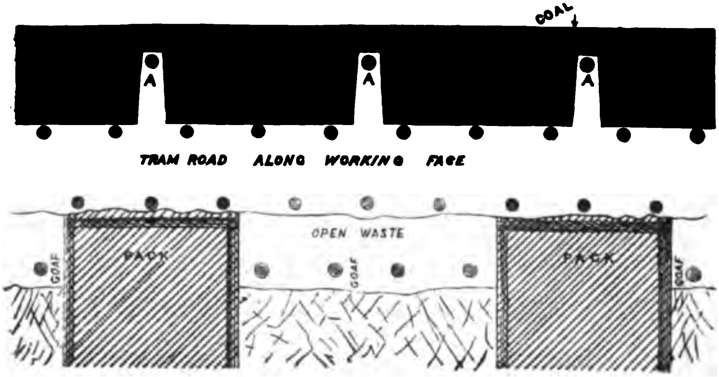

Fig. 66

414. If the seam lies at an angle of 12 degs., and is expected to give off water, how would you work it on the longwall system?

I would drive the roadways through the solid mass of coal to the extreme boundary in the dip, and work the coal backwards or towards the shaft, leaving the goaf behind, as shown in fig. 67.

415. How is a seam of coal, in which the seam lies at a great inclination, worked on the longwall system?

The main roadways are driven through the solid mass of coal in a manner similar to that stated above, and pillars of coal left, as shown at A A, fig. 68, to support them, the mass of coal is then worked away by the longwall system; brows or jigs are carried from this point through the goaf, as shown by dotted lines on the sketch. The coal on the dip is worked away by an engine brow, and when these have reached the extreme boundary the coal is worked away toward the shaft as before.

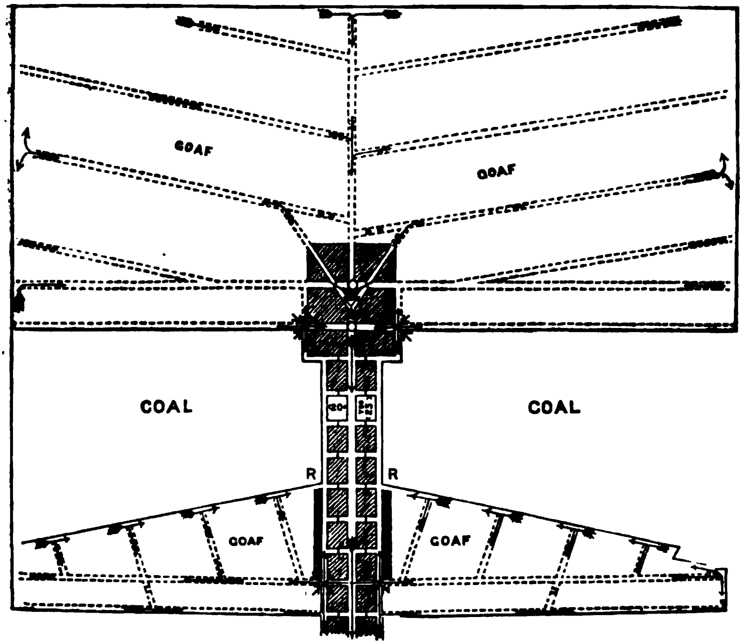

Fig 67.

416. If it is decided to work a seam of coal on the longwall system, what considerations will regulate the opening-out?

Various considerations present themselves. They are chiefly, the character of the roof and floor, the nature of the coal, inclination and thickness of coal, the area of the royalty to be worked, the intended daily output, the quantity of water, and whether it will be better to work the coal on the end or on the face, or half-end or half-face. These and many other considerations decide the direction of the working face, and on the direction of the working face depends, in many instances, whether the colliery shall be carried on at a profit or at a loss. Many collieries are undoubtedly at the present time worked at a loss, which, with the same output, could be made to pay if more regard were paid to the proportion of round coal. It is a fact often lost sight of that a profit can only be realised where a large proportion of round coal is made. The manager should, therefore, have an accurate knowledge of the cleat or grain, so that he may carry his working face to produce the most round coal. Some managers, however, carry the working face parallel with the cleat, because of ease in getting, but without regard to the large quantity of small that will be made. It must be borne in mind that coal will more easily separate parallel with the cleat—that is, when the pressure comes on the edge of a coal face it will fracture and split the coal in the natural line of cleavage, and cause the coal face to grind and crush. When the coal is worked on the end or half-end or half-face (see fig. 67), the pressure will not fracture the coal in the line of cleavage. A long-grain coal will make a much larger proportion of slack when worked off the face than when worked on the end. Generally it will be found better

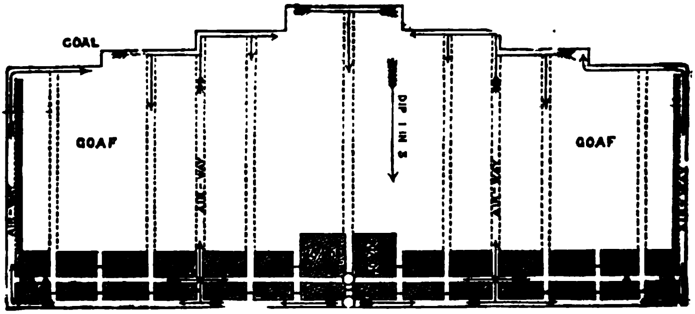

Fig. 68.

to work half-end and half-face. When a seam has an inclination, the author has found by experience that the working face should not be carried in the direction of the dip of the seam, else the pressure is always on the face crushing the coal to slack and breaking the timber. Holing under the coal is more difficult, and there is, besides, the inconvenience of hauling the coals upbrow. When the working-face and horse roads are laid out as shown in fig. 67, the pressure will be on the goaf and not on the face of coal or timber, the coal can be holed to a greater depth, and a larger percentage of round coal is the result, with fewer accidents from falls of roof at the working face.

417. If the seam of coal lies at an angle of 1 in 5, and the roof is very strong, giving no loose *débris* to build the packs, how would you work it by longwall?

Where the roof is strong, giving no loose *débris* to pack with, it is supported by pillars or blocks of coal left on either side of the roadways, generally 10 yards in length and 7 yards in breadth, as seen in sketch, fig. 69. After the first fall of roof, pack walls are built against the sides of the blocks of coal, as shown in sketch. The roof along the wall face is supported by chocks and props. (See fig. 58.)

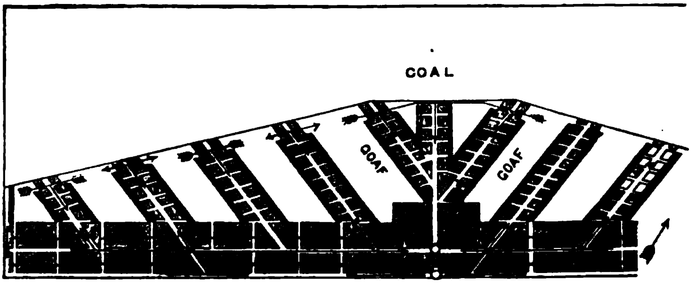

Fig. 69.

418. What is the best method of propping or spragging the coal to protect the workmen during the operation of holing?

There are two methods for supporting the coal while being holed; the first consists of setting short props or sprags at least every two yards; by the second and better method what are termed "cokermegs" are set to support the coal (see fig. 70); these consist of short props or sprags reaching from the floor to the edge of the "curf" of the holing; upon these a prop 4 ft. or 5 ft. in length is placed horizontally along the face, and upon this again another short prop or sprag is set reaching to the roof, the whole structure forming a very good support, especially where the coal is tender.

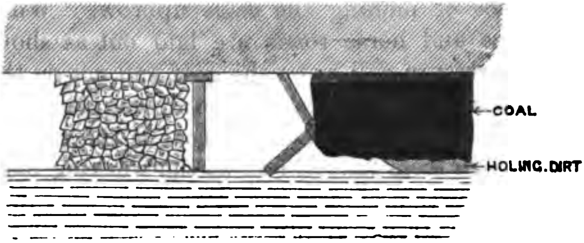

Fig. 70.

419. Have you had any experience in working two seams of coal which lie in close proximity to one another? What are the various methods of working such seams?

In one of the northern counties two seams of coal are found lying very near together, separated generally by less than a yard thick of metal. It is then usual to work the seams on the bord-and-pillar system, common in the north of England, first by taking a lift of about 8 yards wide out of the lower seam; then working down the metal between the seams. The upper seam is worked back immediately over the previous working of the lower seam. The foregoing description applies almost equally to driving "bords" and bringing back the pillars, the only difference being that in the latter case one side of the lift is, of course, loose-sided. Fig. 71 is a sketch giving a general idea in section of this method. Where the intervening strata is much thicker than that before described, it has been found advisable to work the lower seam before the upper one. Where the seams are separated by metal from 10 to 20 ft. thick the following method is adopted:—The roadways are driven in the upper seam, allowing a better roof than if the main roads were in the lower seam. Short cross-measure tunnels are driven to the lower seam at intervals of about 200 yards. From the end of these tunnels a level is driven on each side 4 yards wide for about 100 yards until the levels from the adjoining tunnels are met. Operations are then resumed at the tunnel end, and a rib of, say, 5 or 6 yards wide is taken off the level already driven. This forms a very convenient stowage for the holing dirt, as well as any other metal which would otherwise have to be sent to bank. Special efforts are also made to pack the goaf behind the men as solid as possible. It will be seen that a sort of irregular longwall face is thus formed. The upper seam is then worked off as a separate seam, following the workings in the lower seam, which are kept a little in advance of the upper workings, this having been proved to be the better and safer method. By taking out the lower seam first the upper one becomes

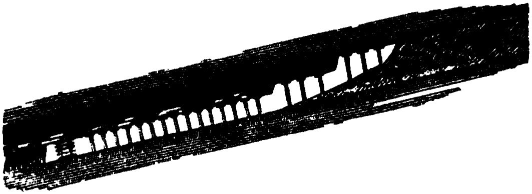

Fig. 71.

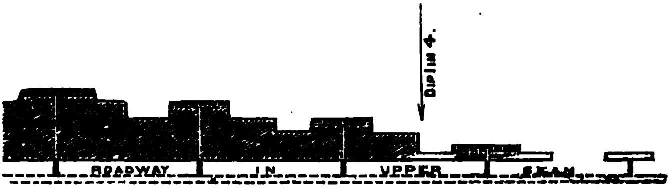

Fig. 72.

somewhat set, and consequently a little more expensive to work, but in some cases this proves to be a benefit, as the coals are often found to yield a much larger percentage of round coal, and consequently realise a better price, more than compensating for the increased cost of getting. The manner of opening out and working the lower seam is illustrated on plan, fig. 72. With careful packing very little timber is lost by this method of working.

420. Have you had experience in working two seams in close proximity to each other on the longwall system, the two seams being separated by only 6 in. of soft dirt, with, say, the lower seam 4 ft. thick and the upper seam 7 ft.? Give methods of working the same.

At the Aldridge Colliery, near Walsall, two seams of coal are found near together, the noted Deep, and the Shallow Cannock Chase coals, separated only by 6 in. of soft dirt, and at that colliery these seams lie about 480 yards from surface. I believe that when working was commenced, the pillar-and-stall system, something similar to fig. 73, was adopted, but this system was soon abandoned, owing to the large proportion of slack made and the great cost incurred for driving headings. The longwall system was then tried, the main roadways being driven in the Deep coal to the boundary, and the Deep and Shallow coals being worked back together. Soon the difficulty of a complete system of packing presented itself. The bulk of the material for packing consisted of slack and the 6 in. of soft dirt between the two seams, and spontaneous combustion or gob-fires were caused by the heating of the slack and soft dirt and the great pressure or friction of the overlying strata on the coal-face. Owing to these fires, stall after stall had to be sealed or dammed off until the whole of the workings were a honeycomb of gob-fires. The flames on one occasion cut off all access to the workings, which had to be abandoned, leaving in all the horses, tools and other material, and to save the other seams higher up, the shaft-bottom had to be filled in some 20 or 30 yards; an idea of the severity of the raging flames may be realised from the fact that the wooden curbs in the upcast shaft were burnt out from between the brickwork for over 100 yards from the bottom, the brickwork itself being in some places melted. The Deep and Shallow coals are now being worked at the above collieries on the longwall system, but instead of driving out the main roadways in the solid of the Deep coal to the boundary, the Deep coal is taken in on the longwall system, that is, the whole of the Deep coal is worked out, and the roadways carried through the gob to the boundary or to a large fault, the Shallow coal forming the roof. The whole of the packing in the excavations between the floor and Shallow coal is done with rock and other material sent in from a seam—the Yard coal—40 yards higher up the shaft. This seam being thin, yields a large amount of dirt which would have to be sent to surface were it not utilised for packing in the Deep coal. I may

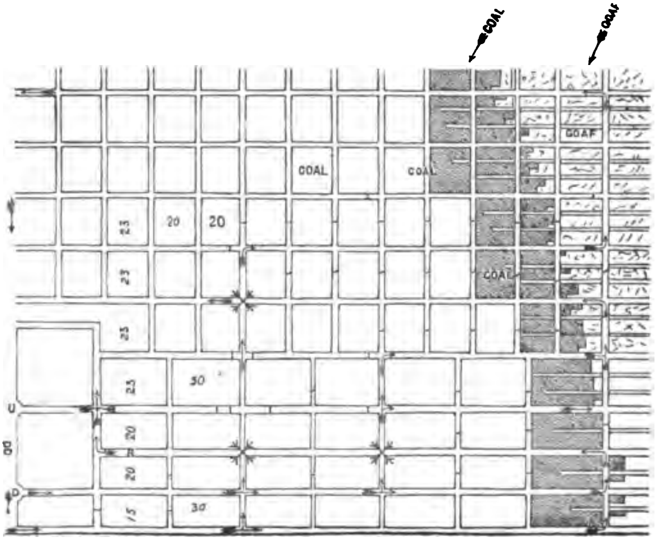

Fig. 73.

here add that to facilitate the conveying of the dirt from the Yard seam to the Deep, at one of the collieries slant tunnels have been driven dipping 1 in 5 from the Yard coal to the Deep; these tunnels also permit the Deep and Shallow coals to be drawn up them and hooked on at the Yard coal inset, thus avoiding the inconvenience and expense of keeping two hooking-on places in the shaft, as well as the expense of maintaining the Deep inset in bad heaving ground, the Yard coal inset costing little to maintain, it being made in sandstone rock. After the Deep coal has been worked away to a large fault or the boundary, and packed as above described, the Shallow coal is brought back on the longwall system, making use of the roadways used in the Deep coal by simply cutting the Shallow coal down, and raising the rails to the required height. The holing in the Shallow is done in the Deep gob; the holing dirt, and *débris* got out from wastes, and rock sent in from the Yard coal, as above-mentioned, form the material for packing in the Shallow workings. To prevent gob-fires we do not allow a long continuity of wastes, but they are built across at every 10 yards—that is, we seal them off by building the packs at the front of them and throwing in new wastes opposite the old packs or cogs. This system of getting the Deep and Shallow coals works very economically, both in the prevention of gob-fires and in the large percentage of round coal obtained from the Shallow seam, for by working the Deep seam first the Shallow is not crushed, but gradually sinks down on the Deep gob, and when working the Shallow back there is little slack, most of the coal being brought out to bank as good round.

421. What are some of the principal causes of spontaneous combustion? How may it be prevented?

The author is of opinion that solid masses of coal scarcely ever fire, and that when a pillar or rib (either left as a shaft pillar or otherwise) fires, it will be found that numerous cracks exist in it, and that it has been crushed more or less by the pressure of the overlying strata. In these cracks or breaks the crushed coal, being in a finely-divided state, developes heat and smoulders, until sometimes it suddenly breaks out in flame. Generally, however, the smouldering may be detected by the smell before the fire becomes visible. Dust or fine slack stowed in underground workings, and exposed to a warm atmosphere, especially in the return air, may condense the gases given off from the coal, and the heat so developed is sufficient to give rise to spontaneous combustion. When timber is left in the goaf, and crushed coal is amongst the packing near the timber, gob-fire is sure to break out sooner or later, especially where the timber is several feet in the goaf from the roadway. Gradually the fire will creep towards the roadside, igniting on its way any timber left in the goaf. The pungent smell and smoke from the timber usually gives timely warning of these fires. Whenever a gob-fire is discovered, whether in coal or goaf, the author recommends its immediate and complete removal or isolation. The excavation should be packed up with gravel, and where the fire has been filled out the roadway should be cased with a wall of rock or brick, the outside of the wall to be "splashed" over with a thin batter of clay, so as to seal off all access of air. To prevent gob-fires the author also recommends that the shaft and other pillars be of as large dimensions as circumstances will permit, and to pack very tightly round the pillars with incombustible material, in order to exclude all air from the breaks, also to keep all slack and timber out of the goaf; and to have a good sweeping current of fresh air passing through the workings to keep down the temperature.

422. Give a description of the Warwickshire coalfield.

The Warwickshire coalfield is the smallest in England next to the Forest of Dean. It extends only from Coventry to Tamworth, a distance of eighteen miles, the average width of proved workable coal being about four miles. This coalfield appears to be singularly free from large faults, having but two, the one running north and south, while the northern boundary of the coalfield is simply one large downthrow fault running north-east by south-west. A large portion of the coalfield is under the Permian; this can be clearly seen by inspection of sections, figs. 74 and 75.

423. What are the workable seams in the Warwickshire coalfield?

There are but few seams of workable coal in this field, which vary in thickness, in depth, and also in the thickness of the intervening strata. The following is a list of the seams which have been and are now being worked, with the sections at some of the collieries. Occasionally, the section is much thicker.

Four-feet coal	4 ft.	6 in.	not now worked.
Two-yard coal	6 „	0 „	
Bare coal......	2 „	0 „	sometimes worked with 2-yard, there being a small parting between them.
Rider coal ...	4 „	0 „	
Ell coal	4 „	0 „	
Slate	6 „	6 „	
Seven-feet ...	5 „	9 „	
Bench coal ...	6 „	0 „	very little worked.

From this section it will be seen that the seams of coal are all of good thickness, but almost all of them are spoilt by an undue proportion of iron pyrites. They lie at a considerable inclination, dipping chiefly due west, generally about 1 in 5, but occasionally much steeper; still they appear to be fairly regular, although from the southern to the northern point of the coalfield the intervening strata gradually thicken out, and the seams of coal diverge more and more from each other. Thus at Hawkesbury Colliery the total thickness from the top of the Two-yard coal to the Seven-feet is 22 yards, whilst at Griff Colliery, about four miles north, the total thickness is no less than 60 yards. This is well illustrated in section, fig. 76.

424. Give a short description of the mode of working the seams in the Warwickshire coalfield.

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The usual mode of working is that known as "fore-winning." Fig. 77 gives a sketch of the method of laying out the workings. It will be seen that the pit is sunk some distance below the seam, and a long flat or skip in the line of dip is made across the measures to cut the coal. After the rise coal has been worked, the main incline is driven to the dip boundary or to a considerable distance, sometimes 900 yards. The coal is then opened out and brought back from this point in two large stalls, which, as a rule, do not exceed 250 yards, though they are sometimes as much as 400 yards wide. When this district is finished slant roads are started out, and the working faces are generally brought back as square as possible, so as to keep the two sides of the stall of equal length. In this way the old goaf roads are left behind, and the coal is gradually won back to the pit bottom. The great objection to the method is that it is impossible to get more coal at a future time, to the dip, as the old drifts through the goaf could not well be maintained, and the risk of underground fires in the goaves would be very great. In the southern part of the coalfield the seams, as stated above, are very close to each other, and when this is the case it is usual to work two or more seams at a time, as shown in fig. 78. At some collieries there are four distinct faces of coal, each 400 yards long (fig. 78), and the Two-yard, Rider, Ell coal and Slate coal seams are worked one in front of the other. The mode of procedure in such a case is as follows:—Two main inclines, one an intake and the other a return, are driven out to the boundary—say, to a distance of 700 or 800 yards, in the lowest of the four seams; a face on each side is then opened out in each seam. Each of these eight

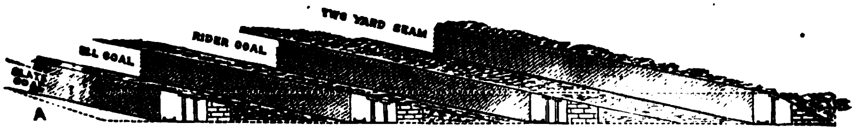


Fig. 78.

faces may be holed every day, and about 50 or 60 tons of coal easily drawn and delivered on the flat, A B, from each; the tubs are then pushed forward to the end and attached to the incline rope, which takes from 12 to 20 tubs at a time, the inclination being about 1 in 5. It is, therefore, good work for one engine to do about 400 tons per day up an engine plane of this length. As will be seen, there are headings between the seams, so that, if necessary, the coal from one seam may be drawn along the face of another, should a fall occur. Another mode of working is the ordinary longwall method, as pursued in Derbyshire, and consists of driving out a pair of headings, with pillars between them from 15 to 20 yards in thickness. This is quite enough to maintain the main roads. Workings are then opened out, with goaf roads every 50 or 60 yards, and the coal is delivered to the main rolley-way by ginneys, which do not, as a rule, take more than three tubs at a time. This method, however, is not found to be so cheap as the former method, on account of the large repairs required in the goaf roads, the roof being in most cases very poor. It is, however, the most convenient method of working to the rise where there is any coal left. For the geological description and the mode of working in the Warwickshire coalfield I am indebted to E. F. Melley, Esq., and also to the North of England Institute of Mining and Mechanical Engineers, who have allowed me to make extracts from Mr. Melley's paper, published in their *Transactions*, Vol. XXXIII., Part IV.

425. A gob-fire is raging, and it is necessary to stop it off with dams or stoppings to prevent the fire spreading and suspending work in other parts or in all the pit. What precautions would you take, while putting in your dams, to guard against an explosion, &c.?

To dam or stop off a part or a district of workings in consequence of gob-fires I should first select the most suitable places for putting in the stoppings, but as near to the seat of fire as possible. In selecting these places I should take into consideration the number of stoppings required, having as few as possible, as the fewer the stoppings the more complete will the sealing-off be. In selecting a place for each stopping I should also take into account the character of the roof and sides, choosing a place as sound and solid and of as small sectional area as could be found. In arranging for the stoppings I should have them prepared and put in as nearly as possible at one time, except at the point at which the intake air enters—that is, I should first seal off the stopping where the return air came out, then follow up sealing the intermediate stoppings between that point and the intake; in no case would I seal off the intake stopping first, as in nine cases out of ten it would then be impossible to approach the return stopping for the smoke and gases given off from the fire; the fire would also spread more rapidly, and any explosive gas would expand. Under these circumstances, there would be, as it were, a partial vacuum formed in workings thus sealed off, consequent on having a draught outlet and no inlet, and most certainly any flame given off from the fire coming in contact with the gas would cause an explosion; if, however, the stopping in the return is built up first, the order of things is reversed—that is to say, the smoke and fumes given off from the fire are held under a partial pressure, the smoke would then act somewhat as an extincteur upon the fire, and any explosive gas present would become non-explosive, and allow sufficient time to seal up the stopping in the intake, which could be performed in fresh air. I may here say, where I have been called on to advise in cases of gob-fires, I have stated my opinion as above, and have seen it put in practical and successful operation; on the other hand, in more than one case where the sealing-off has been begun with the intake, I have known an explosion take place, resulting in serious loss of life and property.

426. Does coaldust form an important element in colliery explosions?

Yes; the important series of experiments upon a large scale which have been carried out by the Prussian Firedamp Commission at Neunkirchen, in the Saarbrücken district, in a specially-constructed gallery of large dimensions, and resembling a mine gallery in its proportions, proves that coaldust is an important factor in explosions. The following are the conclusions of the Commissioners:—(1.) The sensitiveness of dusts to explosion depends not only upon their inflammability or the proportion of combustible matter they contain, but also upon their fineness and certain other mechanical and physical peculiarities. (2.) The presence of fine coaldust in the immediate vicinity of the working-place gives rise to more or less considerable elongation of the flame from a blown-out shot, whether small quantities of firedamp be present in the air or not. (3.) This elongation or propagation of flame by dust is generally of limited extent in the complete absence of firedamp, even if deposits of the dust extend to considerable distances beyond the seat of the shot. The use of coaldust tamping has the effect of decidedly, though not very greatly, favouring this limited propagation of flame by dust. (4.) There are, however, some descriptions of very inflammable dust which, when raised in dense clouds by the action of a blown-out shot and fired by it, will not only continue to carry the flame on, even to distances beyond the confines of the dust deposits, but will also produce explosive effects, in the complete absence of firedamp, which resemble those furnished by some other dusts only when there is a large admixture of firedamp in the air. (5.) All the phenomena produced by the burning and propagation of flame by coaldust are intensified by the presence in the air of only small proportions of firedamp, the required quantity varying with the sensitiveness or ready inflammability of the dust. It has also been demonstrated by the German experiments that a coaldust ignition or explosion, produced in the absence of firedamp, with highly inflammable dust, can communicate ignition to an explosive gas mixture, existing at a very considerable distance from the point of first ignition, and *vice versâ*. It need scarcely be stated that confirmatory evidence was obtained of the fact, first pointed out by Faraday and Lyell, that a firedamp explosion may bring into operation supplementary effects of coaldust, which add considerably to the total destructive effects of an explosion. It appears to be well established that the considerable volume of flame and rush of gas produced by a blown-out shot are indispensable to the attainment with certainty of any of the effects of coaldust enumerated in the foregoing.

427. Can you quote any further authority on this matter?

Yes; great credit and thanks are due to Professor Abel for the light he has thrown upon the subject, and also to Messrs. W. Galloway and R. H. Scott, who have conducted extensive experiments. The result of their investigations showed that a mixture of coaldust and pure air which was not inflammable at ordinary pressures and temperatures would become so if a small proportion of firedamp were added. Coaldust, when raised from the floor and mixed with the air of the mine by some disturbing cause, such as a local explosion of firedamp or a blown-out shot, might thus become the vehicle for conveying flame from one district of the mine to another.

428. Can you give a short detailed description of practical experiments to bear out this theory?

Yes. Careful and elaborate experiments were made by Messrs. H. Hall, H.M. Inspector of Mines, and Clark; to the former gentleman I am greatly indebted for his kindness in furnishing me with a copy of the results of the experiments. The following is a short extract:—"With a view to testing these experiments a slant was driven down from the surface and arched with brickwork a distance of 45 yards and 30 ft. sectional area. Gauze sheets of thin and easily-inflammable material were suspended at intervals of 15 ft. in the slant by means of cross pieces of timber, reaching from about two-thirds the height of the arching, and nearly down to the thill, and in each cross piece of timber small holes (1 in. diameter and 2 in. deep) were drilled, so as to face the blast, and these were filled with fine gunpowder. The charges were fired from a strong iron tube, 2 ft. long and 2½ in. diameter; the thill for 8 or 9 yards from the face was thinly covered with coal-dust obtained from the screens." In their fourth experiment under this head, they say, "Coaldust having been scattered on the deals the whole length of slant, the thill being very wet, fired 2½ lb. powder; in this case flame issued strongly at the mouth of the slant, having travelled 45 yards. The blast was very fierce, and would certainly have proved fatal to anyone struck by it in its course. It was noticeable in these experiments that not only was the flame largely increased, but the blast was also proportionately greater, and bearing in mind that the floor of the slant was very wet (dripping), and the temperature low (50 degs.), we may fairly assume that in dry mines at a high temperature and where the roads are always thickly covered with fine dust, this dust will play a considerable part in extending and adding to the destructiveness of an explosion."

429. In working a dusty mine where firedamp is given off, what steps would you take to guard against an explosion?

Dusty mines should be ventilated by fan ventilation, and the air when it has passed through one district should not be allowed to pass through another, but be carried direct into the return airways—that is, each district should have its own intake and return. The intake airways should be constantly damped with water where the floor is strong. The water may be readily obtained by means of small pipes carried from the rising column of pumps or from lodges in the shaft or from the surface. If the floor is soft, and one that will lift or yield when damped with water, then common salt may be advantageously used as a substitute. The gases given off from common salt when dissolving or evaporating have also a tendency to render harmless or dilute any small percentages of fire-damp that may be contained in the air.

430. Are you acquainted with any special inventions for laying the dust in the roadways of mines?

Yes; one invented and patented by Mr. Wm. Blakemore, M.E., F.G.S., Cardiff, who furnishes the following description, illustrated by figs. 79 and 80. The invention consists of a water-pipe led through the heading, into which at suitable intervals a T-piece is inserted, with a reducing side having a valve or cock, A (fig. 80). The pipe is fixed in a suitable place, and held in position by hooks; connected with it is another series of pipes perforated with small holes through which the water is forced and spread over the opposite surfaces, or a spreading jet or rose may be inserted, as at B, fig. 79. The supply can either be had from the surface direct, and the pressure reduced if necessary, or the water may be drawn from a tank placed at a suitable height in the shaft, and a cock inserted in the standpipe leading to the pumps, or it can be pumped in or forced by an injector. The advantages claimed for this invention over watering by means of a tank, are—

(1.) That the watering can be done during working hours. Each section can be worked in a few minutes or the whole done simultaneously for 400 or 500 yards. By opening the cocks in the perforated pipes before turning on the water in the main pipe, when the main cock is opened the water would rush through the small holes; the attendant could then shut the small valves one by one, thus allowing the last pipe to have the full pressure, for a short time at least. This mode of procedure will do away with the necessity of a very large main pipe.

(2.) The passage of the trams would not be delayed during the watering, nor the output interfered with from this cause.

(3.) No extra cost for man and horse at night time, or stoppage of empty trams returning to the workings.

(4.) The water which may be sprinkled during the night (unless done to a large amount), will be evaporated early in the daytime, and the annoyance and danger of coaldust will be as great as ever until the next watering, which with a tank cannot take place till the day's work is finished.

(5.) By judicious placing of the holes, the roof, sides and the floor of a heading can be watered.

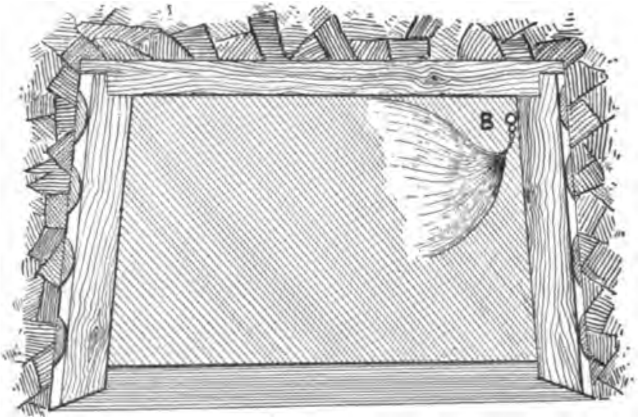


Fig. 79.

(6.) On account of the smallness of the holes the water will be forced through in a fine spray resembling rain; this will cover a large area while falling.

(7.) The water will moisten and deposit a great percentage of the coaldust suspended in the air.

(8.) The water will be in contact with the air at a great number of points, reducing the temperature.

(9.) The particles of water, being very light, will be carried along with the air current, and will thus be forced into all corners.

(10.) The water will be forced in an oblique direction by the air, and still more spread, thus preventing the formation of pools.

(11.) The water being in the form of spray will effectually mix with the carbonic acid gas, and take up a larger amount than if only spread on the road.

(12.) A lad can attend to the pipes and cocks, and even the services of the tram driver can be used when he finds the air laden with coaldust.

(13.) No heavy expenditure after the first outlay.

(14.) No hose pipes to be cut by the tram-wheels.

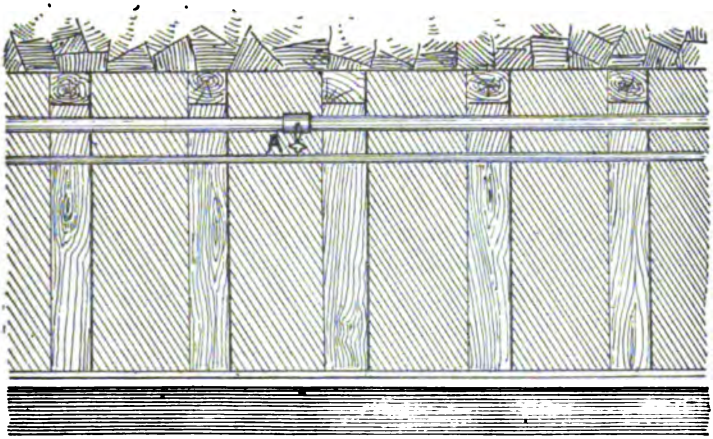


Fig. 80.

(15.) In the case of fire the spray would be a most effectual extinguisher.

(16.) Should the pipes be untouched in part of the headings after an explosion the spray could be used to reduce the amount of carbonic acid which is in the mine, and allow an earlier entrance into the mine. (In his work on mining, Mr. G. G. André says 1 cubic foot of water will absorb 1 cubic foot of carbonic acid gas.

Another* apparatus for laying the dust in the workings is manufactured by the Birtley Iron Company. It consists of a very ingenious tub, of which fig. 81 is a side view, and fig. 82 an end view. The tub is made of steel, built on a wooden frame. An india-rubber cord passes over the end of the valve spindle, and is attached to the brass casting. There is a hollow boss cast on the water spindle, with holes in its circumference for the exit of water, and similar holes through the boss of brush; on account of the smallness of the holes the water is forced through in a very fine spray, which lays the dust very effectually—acting on the roof, floor and sides at one time. The tub can be attached behind a gang of tubs drawn by a horse, or to the rope on the engine plane, any time during the day without interfering with the working of the colliery. With the tub running

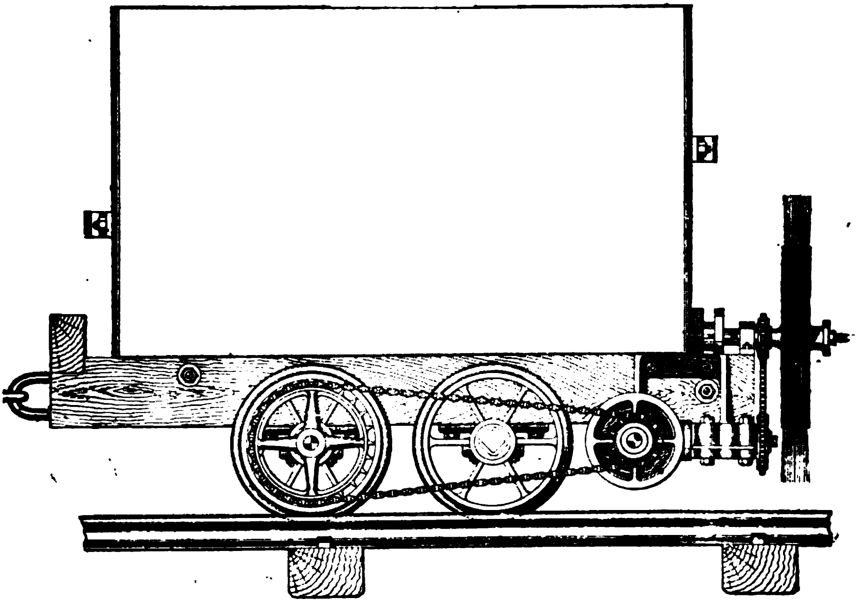


Fig. 81.

at a speed of 2½ miles per hour, the brush revolves at the rate of about 450 times per minute.

431. What are "chocks?"

They are pieces of hard wood cut from rough oak, usually bought by weight, averaging from 15s. to 30s. per ton; they are sawn into pieces 3 ft. long and 6 in. by 6 in. in section.

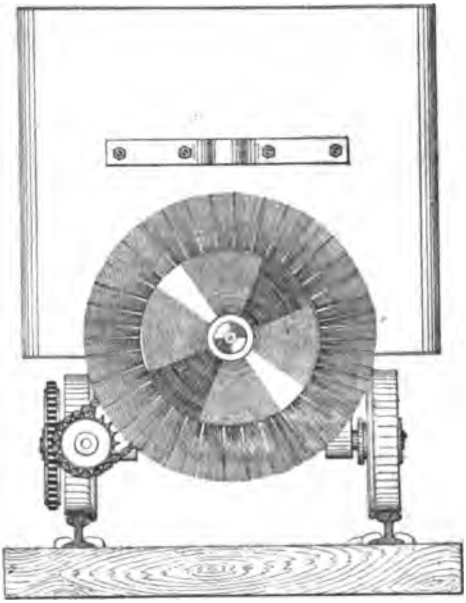


Fig. 82.

432. How would you put your chocks in along the wall face to get them out again?

I should put the two bottom pieces on a few inches in thickness of fine *débris* or slack; they may then be easily taken out when required.

433. Are the chocks always set perpendicularly? if not, state why.

In a seam lying perfectly horizontal, the props and chocks are set perpendicularly between the roof and floor, as shown in fig. 58. When the seam is highly inclined they will be set at right angles to the floor, but not perpendicularly—that is to say, if the seam lie at an angle of 15, 20 or 30 degs., the chocks must be set at the same number of degrees from the perpendicular, as seen in fig. 83.

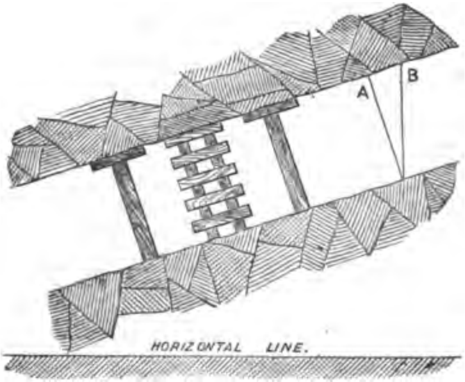
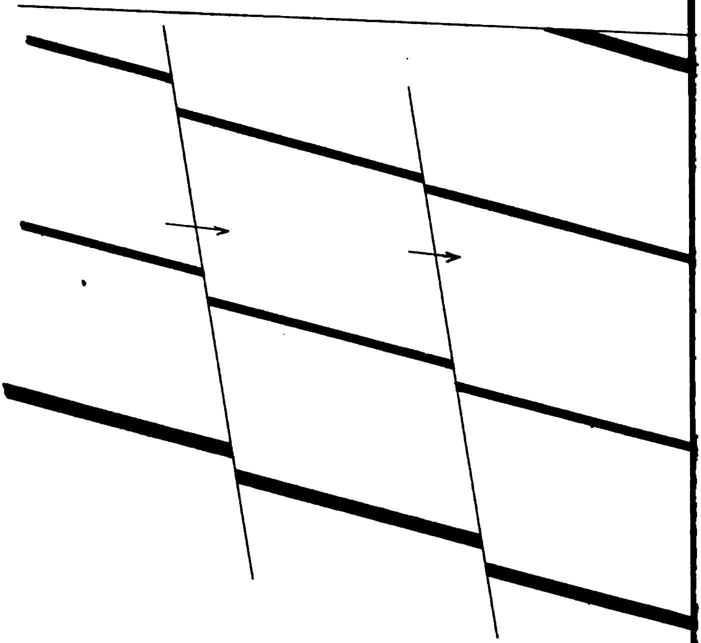


Fig. 83.

In a seam lying at an angle of 18 degs., the props, &c., will require setting as seen at A; it will be 18 degs. from A to B, the latter being the perpendicular. If not set in this way the pressure of the roof will have a tendency to crush them out.

434. By what system is a seam of ironstone usually worked?

Ironstone is generally worked by the longwall system, being either stratified or existing in the form of nodules in strata of metal or shale. In some parts of North Staffordshire, where the seams are of great thickness, it is worked by the pillar-and-stall system, but the seams of ironstone in South Staffordshire and other districts are wrought by the longwall system in a manner similar to that described in regard to coal seams.



435. Give a section of a coalfield that is not adapted for longwall.

Fig. 84 is a section of part of a coalfield that is not adapted for the longwall system. It will be seen that it is much broken up and traversed with faults, and each time the wall face is worked up to one of these faults the whole seam disappears and that part of the workings is abandoned for coal-getting until the seam on the opposite side of the fault is opened out again by new headings.

436. In working a seam of coal on the pillar-and-stall system, what size would you have the pillars?

The proper size for the pillars depends, in a great measure, on the depth of the seam from the surface, and the strength of the roof and floor, as previously stated.

437. In working pillar-and-stall, how would you arrange the pillars?

I would arrange the pillars in one district so that I could begin to work them away as soon as the straight work in the district was finished, because when pillars are allowed to stand the coal deteriorates in value, and a great number of roads have to be ventilated.

438. How would you guard against thrust?

If the roof and floor are of an unyielding nature, and the coal soft, I would have the pillars made large.

439. What is meant by the term "creep?"

When the roof and floor are soft a squeezing process takes place, causing the roof to bend downwards and the floor to heave upwards, thereby lessening the height of

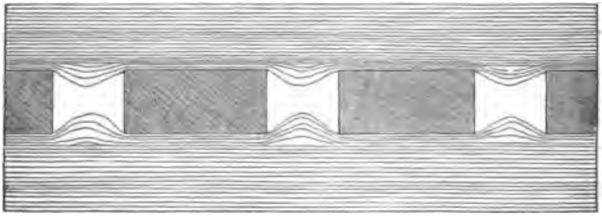


Fig. 85.

the roadways. A good illustration of this is seen in fig. 85. When the creep once sets in, it will spread itself over the whole district. Many good collieries have been ruined, and thousands of acres of valuable coal lost through having the pillars of too small dimensions.

440. Give a sketch of the mode of pillar-and-stall work.

Fig. 73 is a good illustration of this system as usually adopted in Lancashire. The pillars left to support the main roadways are 20 × 30 yards, and in some cases 23 × 30, those in the workings 20 × 23 yards. In some districts headings or splittings are driven through the pillars, as seen at E, fig. 64, but this should not be done until the boundary is reached, for it will have a tendency to bring on a thrust or creep, and when the pillars have to be worked away there is a large amount of small coal. The removal of the pillars or broken work should follow the splittings; then the expense of keeping up the roadways and airways will be reduced to a minimum, and the coal will be wrought in a good condition.

441. By what system is the Ten-yard coal of South Staffordshire usually worked?

By the pillar-and-stall system.

442. Give a short description of the working of the South Staffordshire Ten-yard seam.

The main levels or gate roads are carried forward in the lower layers of the seam to the boundary. Out of these gate roads a heading is driven, termed a bolt-hole, about 10 yards in, as shown at A, fig. 86; stalls are next driven in the lower layers as before, forward to B and other stalls to C C. This operation is termed in South Staffordshire opening a side of work. Other stalls are then driven forward and across. The width of these stalls varies considerably, according to the strength of the upper portion of the seam, but we may say that the average width runs from 5 to 10 yards, and in some instances the author has known them to be driven even to a greater width than this. These stalls are driven at opposite angles to each other to form square blocks or pillars of coal. The pillars also vary in size according to the strength of the upper portions of the seam; the size of these pillars varies from 8 to 20 yards square. The number of pillars in a side of work is from four to nine, but usually in each side of work there are six or eight pillars. This mode of working is termed getting the coal by square work. The sides of work are divided one from another by barriers of coal, termed fire-ribs, as shown on plan, and a narrow road is driven up the middle of these ribs between two adjoining chambers, and other bolt-holes cut through into the chambers at suitable intervals, as seen on plan. These are the airways made to allow the air to pass through after it has ventilated the side of work. They are usually driven in the upper portions of the seam, as shown at W, fig. 87, thus preventing light carburetted hydrogen gas

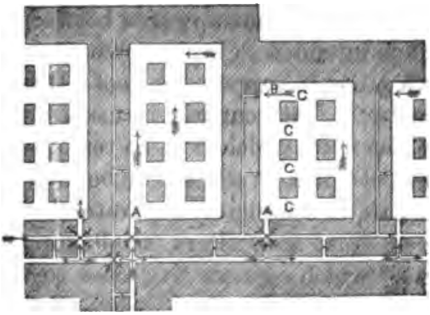


Fig. 86.

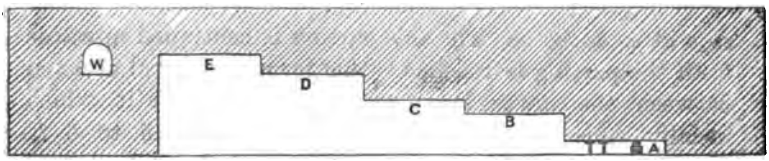


Fig. 87.

from accumulating near the roof, for owing to the lightness of this gas, it has always a tendency to find its way to the roof in underground workings. The first operation in working this seam is to undercut in the bottom part of the seam (see at A on plan), and short wooden props, termed "puncheons," are fixed to support the mass of coal. After a sufficient length of coal has been undercut in this manner, a vertical groove is next cut upwards between the mass of coal which it is intended to bring down, and that which is to remain as a pillar to support the roof; these are termed "holes of sawyer." This cutting is usually performed on both sides of the mass which is to be removed, and also at the end where it joins on the fire or boundary rib. As it would not be safe to completely separate the mass of coal to be removed from the pillars, small supports are left, called "spurns," which connect the mass to the pillars, as seen at A A, fig. 88. The side cutting is continued upwards until the parting is reached; this forms a natural division between the lower layer and the next above it, which usually runs in the "sawyer layer" from 5 to 6 ft. Spurns are usually left at intervals of 6 ft., each 6 ft. of cutting being connected with its neighbour at the upper part, as shown at E E, and divided from it at the lower part by the spurns. After the cutting up is completed the puncheons and spurns are taken or jobbed out with a long pricker, much resembling a boat-hook or shaft, and the whole mass of coal falls together, several tons in weight, according to the area of the excavation. In this

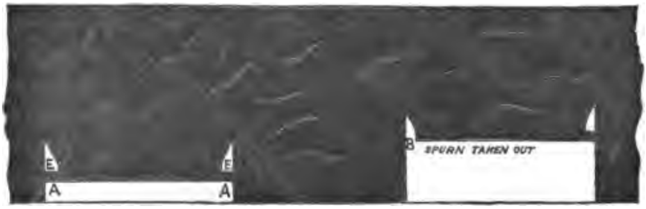


Fig. 88.

manner the coal is taken down, layer after layer, as seen at fig. 87, A B C D E, until the upper layer next the roof is reached. The removing of the upper portion of the seam offers much difficulty and danger, which, however, is obviated by fixing scaffolds against the sides of the pillars for the workmen to stand upon while performing the side cutting. When the last layer or bed of coal has been removed in this manner, the roof, of course, breaks down and chokes up the excavations. This is generally called a fall of "shut," and when it occurs dams are required to be put in the bolt-holes. These dams usually consist of two walls of brick and mortar, with sand packed tight between them, and are designed to exclude the air from the "shut."

443. Has there been any recent modification in the mode of working the Ten-yard seam of South Staffordshire?

Yes; a slight modification. Twenty years ago, the system of ventilation was by driving headings in the top coals, as described in the last question. Now, however, parallel gate roads are driven from the shaft to the boundary, and the air heading is dispensed with. The sides of work are opened out, as described in the last question, except that sometimes timber cogs are placed between the pillars in the openings (C, fig. 86.)

444. Give a sketch illustrating the benefit of splitting the air.

It will be seen by referring to fig. 89, that the air is only divided into two currents, and, as indicated by the arrows, each current is brought nearly to and taken from the pit in several places. This means an in and out or up and down route for the air, as it has to pass in one current almost all round the workings, besides meeting with obstructions from a great number of doors, regulators, &c. By referring to fig. 90, which is a plan of the same workings, it will be seen by the arrows that the air is split at and near to the downcast shaft into four distinct currents, and that each current only travels one-fourth the distance in this case that it did in the former, and no doors, regulators, &c., are required.

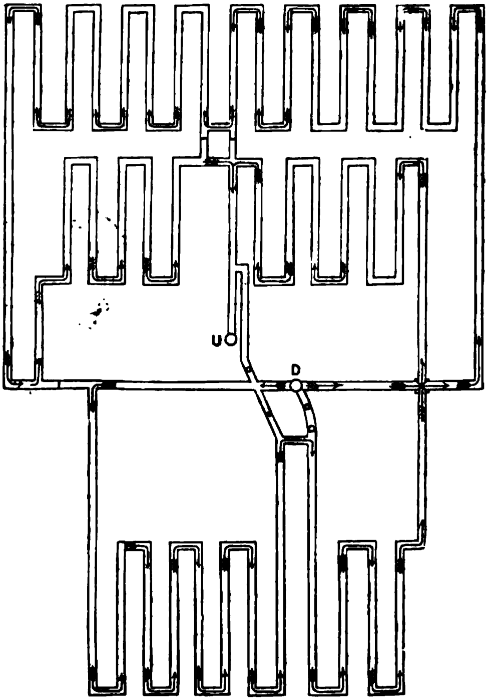


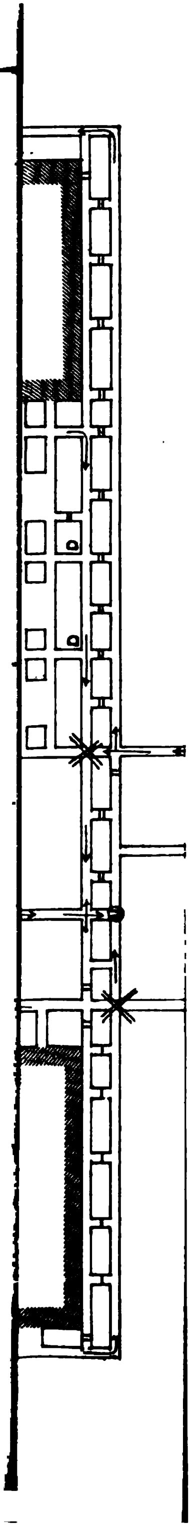
Fig. 89.

445. Give a sketch plan such as would be given to candidates at examinations to show how workings should be ventilated.

Figs. 91, 92 and 93 are such plans. These plans are filled up and marked, and ventilated, &c.

446. Is any one method or system of ventilation applicable to all mines?

No; but the author has always found it best to carry the intake air to the lowest point in the workings, then up-



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hill along the working face, and this he recommends to be done at almost any cost. He also recommends that the return air should come out at the highest point of the workings, and that a few openings be made into it from the goaf, so that any gas given off from the goaf will pass direct

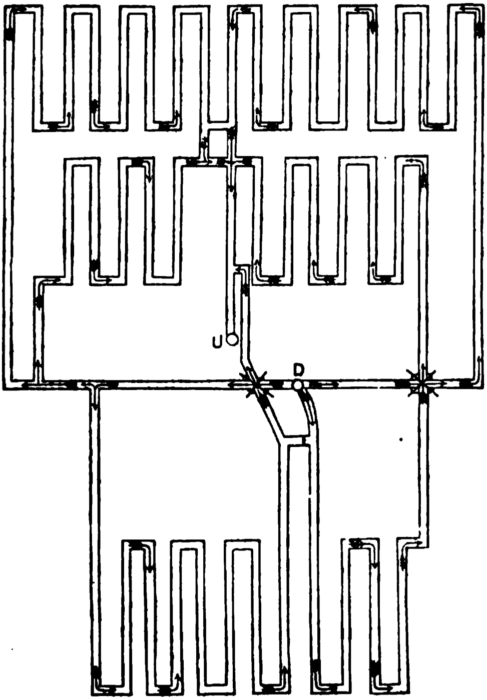


Fig. 90.

into the return air and not into the workings. When the intake air enters the workings at a high point and has to be forced downwards to a low point, and again return up to the upcast, there is great loss in ventilating power, and any gas given off from the goaf makes its way to the working face. Underground workings vary so much in character and detail that no rules would be universally applicable; only great skill and foresight on the part on the manager can provide for each emergency as it arises.

447. If you had four separate districts of workings, would you connect them all together? If not, give your reasons.

I should not connect the districts, the advantage being that if an explosion occurred, it would only affect the one district, or if a gob-fire broke out in one of the districts it would only be necessary to stop that district, either to flood it or otherwise to extinguish the fire.

448. If, in working with furnace ventilation, an explosion of firedamp take place, and your return air passes over the furnace, all your men being at work at the time, what immediate steps would you take to get them out of the mine?

I should descend the shaft and have the furnace fire damped out, keeping up the ventilation by steam jet, waterfall or some other mechanical appliance; while this was being done I should start as many hands as convenient, repairing air-crossings, stoppings, doors, &c., and at the same time getting the men who were alive to surface.

449. Your upcast shaft being cased with tubbing, and the ventilating furnace placed at the bottom of it, what would you do first, supposing the tubbing burst, and the water running in turned the ventilation?

I should send messengers to all parts of the underground workings to bring the men out, and at the same time get the fire out of the furnace as quickly as possible.

450. The side of your shaft falling in, what would you do?

Secure the top part with chains and get down to where it was solid, then put in a crib. If the ground were very bad I should first put in a square crib, and a round one on the top of it, and then commence building it up with bricks and mortar, packing it well with fine ashes.

451. Your downcast shaft freezing and endangering the men's lives when going up and down, what would you do?

I should put in a small steam jet.

452. Suppose you have a pit sunk to a seam of coal, say, 100 yards down, and the seam lying at an angle of 12 degs. If, in working the seam to the rise of the pit, at a distance of 20 yards, you meet with a fault which proves an upthrow of 30 yards, and in working to the dip, at a distance of 23 yards, you meet with another fault which proves to be a downthrow of 40 yards, what would you do in each case to strike the coal again on the opposite sides of the faults?

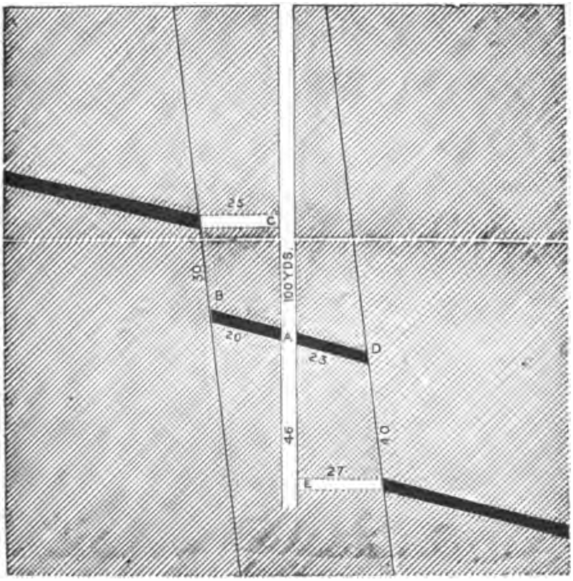


Fig. 94

As these faults are large ones and near the pit, I should drive a horizontal tunnel up the pit at C, fig. 94. This would win the coal again on the opposite side of the fault at a distance of 25 yards which must have been at one time in a line with A B D. To win the coal on the opposite side of the fault (on the dip side) the pit would require sinking 46 yards deeper, and a horizontal tunnel driving a distance of 27 yards at E.

453. If the seam lie at an angle of 1 in 5 and when driving out your levels you meet with faults, taking the coal away, would you start a horizontal tunnel on the rise side or dip side to recover the coal for an upthrow or downthrow fault?

For an upthrow fault I should start the tunnel on the lower side of the roadway, and for a downthrow fault on the rise side.

454. If, in driving a level in the coal, you met with a fault lying to at the foot and leaning back at the head, would you conclude it to be an upthrow or a downthrow?

I should conclude it to be an upthrow; but if it lay back at the foot and leaned to at the head I should consider it to be a downthrow.

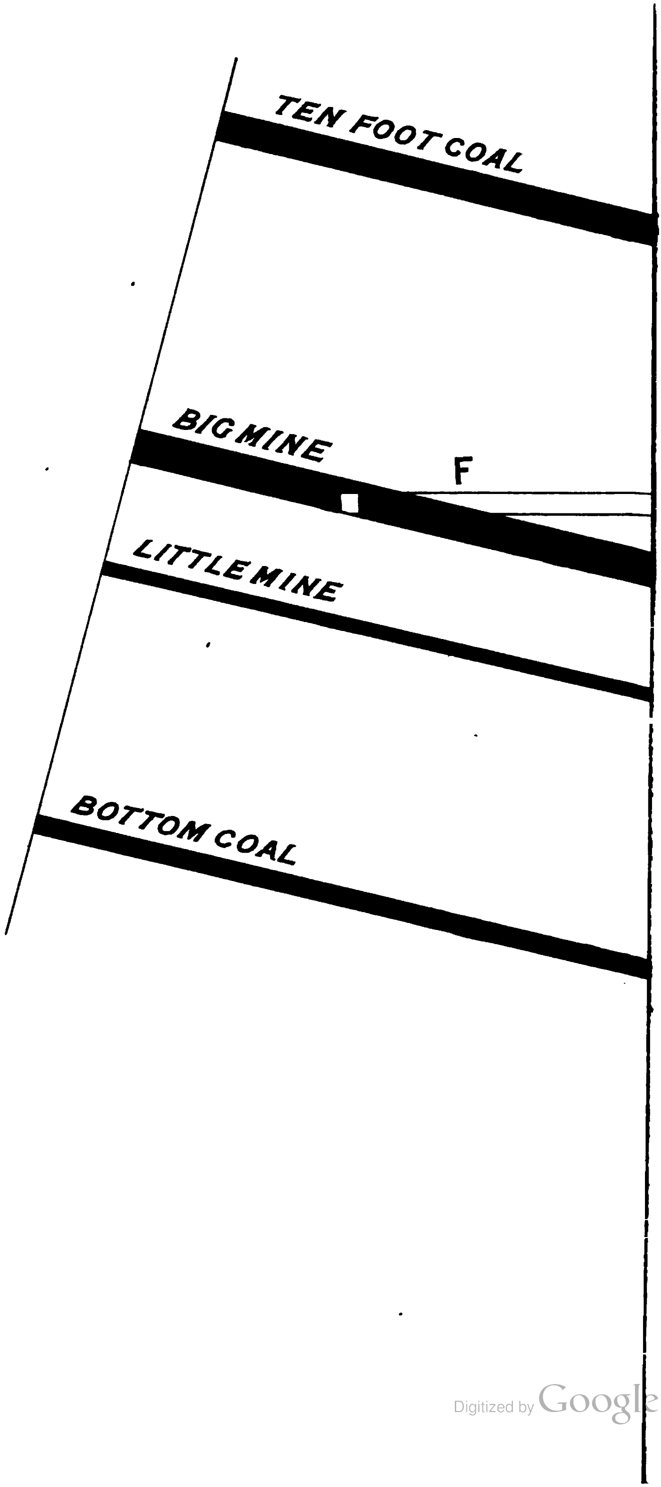
455. If in driving in the coal you met with a fault quite perpendicular, how would you ascertain whether it was an upthrow or a downthrow?

I should drive a tunnel through the listing of the fault into the solid strata, and by a knowledge of the strata which overlie or underlie the seam I should be able to ascertain whether it was an upthrow or downthrow, and nearly its size.

456. When driving through the listing of a fault without any knowledge of the strata on the opposite side, how would you ascertain whether the fault was an upthrow or a downthrow?

Having no knowledge of the strata, I should put a borehole up in the roof, and another down in the floor until the seam was reached either above or below.

457. If in driving in the coal you come to a point broken up by a series of faults, and in driving your tunnel through this broken ground you come to the solid strata again, how can you ascertain whether the coal is overhead or beneath?


TEN FOOT COAL
BIG MINE
F
LITTLE MINE
BOTTOM COAL

I should put a borehole up in the roof and another in the floor, as shown at A B, fig. 95, until satisfied that I had recovered the coal either above or below. It will be seen that in driving this tunnel a large number of downthrow and upthrow faults and broken ground were passed through; and it was proved by the borehole that the coal at D was not disturbed out of its line parallel to the coal at E. The tunnel was carried forward to the big mine at F, and another tunnel driven to win the Ten-feet coal, as shown by dotted lines at E D.

458. Explain briefly how outbursts of gas occur?

Outbursts of gas may occur in many ways. The pressure under which the gas has been retained may lift up the floor or break down the roof of the mine; or a sudden fall of the barometer may allow gases that were pent up in goaves and abandoned excavations to expand in volume consequent on the reduction of the pressure or density of the air, which is what the barometer indicates; or a fault or throw may be cut through by an advancing gallery at a point opposite, or nearly so, to some coal seam, cast up or down by the fault, and holding firedamp under a higher pressure than that in the seams or strata through which the gallery has been driven. In such a case the fire damp will at once commence to move in the direction of the least resistance, and this will be towards the advancing gallery. The author has had several cases in which the pressure of gas has forced out the solid face of the advancing galleries; in one instance, over 4 ft. of the face of the stone drift being blown out, the gas escaped in such quantities that it fouled the whole air of the mine in its course to the upcast pit, and in a few minutes would fire in a safety lamp at the top of the upcast shaft. So great was the volume of the gas and so violent was its escape that for two months the noise of this blower could be heard at a distance of 50 yards.

459. Would it be possible, with such an outburst of gas, for an explosion to take place, all the workmen engaged in the mine being provided with locked safety lamps?

Yes; if the gas came in contact with any naked light or exposed flame—say, at the ventilating furnace, or, with a flame caused by spontaneous combustion, or some defect in a safety lamp, such as a displaced or broken wire—it might render the lamp no better than a naked light; or with a lamp hanging or being carried in a slanting position, the gas might stream out with such force as to propel the flame at once through the gauze, thus igniting the gas outside. Again, a lamp will burn as long as it is supplied with oxygen, and, if left hanging in the gas, the gauze being made of thin iron wire, would soon become heated sufficiently to ignite the gas outside, or a reckless workman may tamper with his lamp. An explosion may occur from any of these causes where there is an outburst of gas, even though the manager has taken every precaution his skill and foresight could suggest to guard against them. In mines subject to outbursts, or where there is probability of an outburst, the ventilation should be so arranged that each district has a separate intake and return to obviate the return air from one district passing or coming in contact with the return of other workings or districts; and, if furnace ventilation is in use, the return air should come out through a dumb-drift into the upcast shaft at a sufficient distance above the furnace drift, so that, should an outburst of gas occur at any time, it would not come in contact with the flames from the furnace. The author, however, strongly recommends fan ventilation, especially for fiery mines, so avoiding any possibility of accident from this cause.

460. What precautions would you take to guard against sudden outbursts of gas when driving stone-drifts to win coal dislocated by a fault?

When a fault or throw is being cut by an advancing stone-drift to win a seam of coal dislocated by the fault, a borehole should be kept sufficiently ahead of the working face in order to tap the gas gently and in such quantities as can be safely dealt with. It may be of service here to give one or two cases of outbursts with which the author has had to contend. About 1,000 yards from the pit-eye a downthrow fault was struck in a jig-brow. The coal was thrown down 24 ft., and it was determined to drive a horizontal stone-drift to recover the coal. The gas was, however, retained in the coal under such great pressure that when the drift was within a few yards of it the gas burst the face of the stone-drift without the least warning, and so fouled the air of the underground workings that in ten minutes it would fire in a safety lamp at the top of the upcast shaft. Fortunately the gas did not come in contact with any naked light, and the men were drawn to surface by the intake airway without any mishap. The blowing out or noise of the gas could be heard at a distance of fifty yards from the face of the drift, and continued to be heard for two months afterwards. When it was possible to approach the face of the drift with safety, it was found that the gas had blown out solid strata 4 ft. 1½ in. in thickness, somewhat as shown at B, fig. 96; it was also found to have crushed the greater part of the blown-out rock to a powder. The gas must therefore have been confined under a total pressure of something like 31,503 tons.

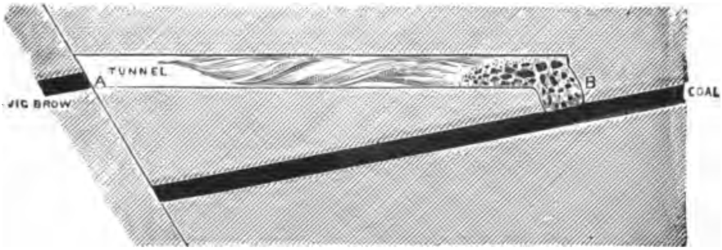


Fig. 96.

461. How do you arrive at the above figures to calculate the pressure under which the gas was supposed to be retained?

My figures are, of course, only an approximation, the following being the method by which I arrive at them.

I take the tensile strength of the rock at 10 tons per square inch, and suppose that the breaking strength of the rock varies directly as the breadth of the rock, and directly as the square of the depth, and directly as the tensile strength of the rock, and inversely as the span. I also take 7 ft. as the span, being the width of the drift, and 6 ft. as the breadth, being the diameter of the hole at which the gas blew out. I have also taken 4 ft. 1½ in. as the depth, being the thickness of the rock blown out. The formula will read thus:—The breadth multiplied by the square of the depth, and by the ultimate tensile strength per square inch of the rock and divided by the span. Thus, $\frac{b \times d^2 \times c}{l}$ = pressure in tons. Then in the example, $\frac{72 \times 49{\cdot}5^2 \times 10}{84}$ = total pressure in tons. In the above calculation I have only taken the rock as supported at both ends and the pressure applied at the centre, but in the case in point the rock must be taken as being in the solid strata or fixed, and the breakage pressure as equal to 1·5 times the pressure it would have been had the rock been only supported. Example: $\frac{72 \times 49{\cdot}5^2 \times 10 \times 1{\cdot}5}{84}$ = 31,503·21, total pressure in tons.

462. What method did you adopt to complete the driving of the tunnels above described?

To complete the driving of this stone-drift or tunnel to the level of the coal, I first had the coal got out a sufficient distance, and afterwards the roof taken down. The coal still giving off gas, blasting was out of the question, and as the roof was very hard I had it ripped down to the level of the coal by means of the patent multiple wedge. This wedge is a great improvement on the old system of plug and feather wedge. The driving wedge is divided into two equal parts, each of which is driven separately and alternately, thereby obtaining a much greater expansive force with less driving force. The holes were bored with

Fig. 97

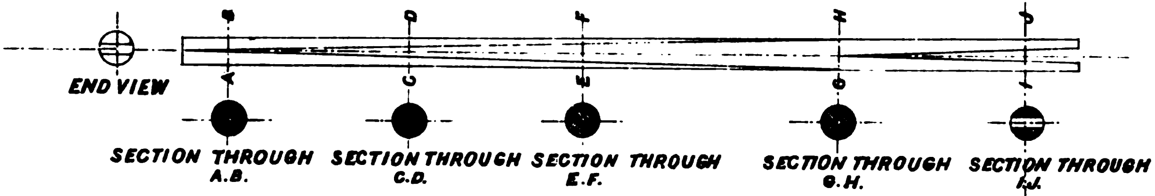
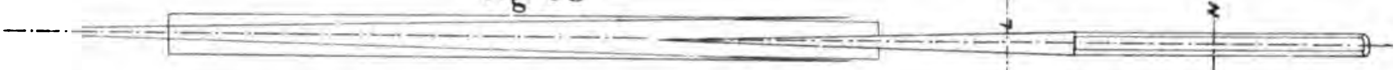
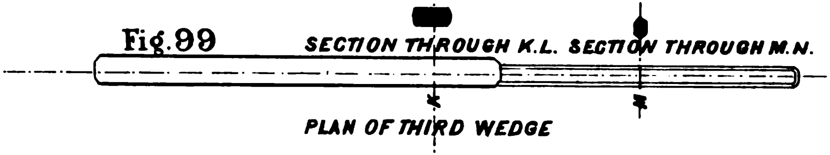


Fig. 98



PLAN SHEWING TWO WEDGES DRIVEN UP & A THIRD INSERTED READY TO BE DRIVEN UP

Fig. 99



PLAN OF THIRD WEDGE

Scale – ¼ in to 3 in.

the Macdermott rock perforator, which machines are best adapted for the wedge in question, the holes being uniform throughout. For drawings illustrating the wedge, see figs. 97, 98 and 99.

463. Have you had other experience than the above, and what precautions have you adopted?

Having had occasion to drive other stone-drifts since the one above referred to, and under similar conditions expecting the coal to give off gas when struck, I put boreholes down in the floor of the drift with the rock perforator, 9 ft. in length towards the seam and 5 yards apart, or at intervals of 5 yards, as shown at A B C, fig. 100. When the borehole C had been made about 8½ ft. the gas was tapped and escaped through it gently, thus avoiding a sudden outburst Instances have come under my observation where stone-drifts were being driven to recover a seam of coal and the gas from the coal above has burst the roof of the drift down at the face, and for 20 yards along. Therefore I recommend, and speak from experience, that boreholes at least 9 ft. in length be put in every five yards, when driving stone-drifts to recover a seam of coal dislodged by a fault, and which is likely to hold firedamp under pressure. The cost of boring holes such as are shown at A B C, fig. 100, need not increase the cost of driving the stone-drift more than 6d. per yard if put in with the perforator. Boreholes should also be kept a sufficient distance ahead of the working face when approaching old or abandoned workings likely to contain gas.

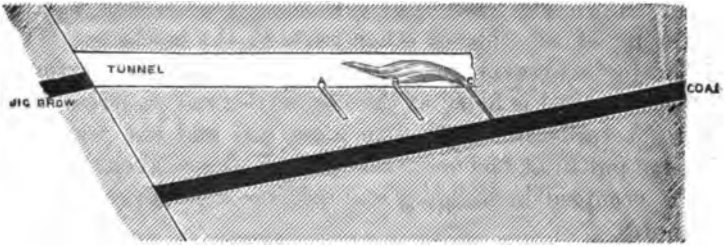


Fig 100.

464. Where gunpowder is prohibited, what means would you adopt for falling the coal when undercut?

Owing to the number of alarming explosions that have occurred and that are occurring, numerous experiments have been made with the object of superseding gunpowder by the use of mechanical appliances of various design, but with only partial success. In the Lancashire districts there have been recent experiments made with several wedges, each differing in construction and first cost; some worked by hydraulic power and others with compressed air. Experiments have also been made with the multiple expanding wedge, which is fully illustrated in figs. 97, 98 and 99. This wedge is recommended on account of its simplicity, effectiveness, safety and cheapness. Wedges worked by hydraulic power or compressed air are very costly and expensive to keep in repair, and are very dangerous to those engaged in using them; they have to be driven at a great pressure to bring down the coals, and this sometimes results in the bursting of the tube or other parts of the machine. The following is an average of the work this wedge will perform, where the coal is holed at the bottom:—Coal undercut 4 ft. 6 in., 5 yards in length, one loose end and one fast end, wedge put in at fast end; coal brought down, about 8 tons; time occupied in wedging and drilling hole for wedge, 24 minutes.

465. Can you give a detailed description and sketch of a good hydraulic coal-getter?

Yes; fig. 101 is a sketch of the Cunliffe patent hydraulic coal-getter, probably one of the simplest and most economical mechanical substitutes for blasting yet introduced. Unlike other coal-getting machines it is not a wedge, but exerts its force in a horizontal direction. The machine is simple to operate, and can be worked by any ordinary workman without special training; it is very portable, the weight not exceeding 40 lb.; the first cost is not great, and with the machine it is not necessary to hole the coal to so great a depth as where an explosive is used.

The *modus operandi* is as follows:—After the hole has been drilled 3¼ in. diameter the working barrel, B, is placed in and well to the back of the hole, the two semi-circular keys, D D, are then tightly driven in, when the head, A, may be screwed on and the pump actuated. In most cases the charge of water in the head, A, will be more than sufficient, and the whole operation (after the hole is drilled) need not exceed 5 minutes. The machine has been very favourably received, and is now in use at several collieries, and is well spoken of by H.M.'s Inspectors of Mines, and bids fair to be a successful substitute for explosives in the working of gaseous mines.

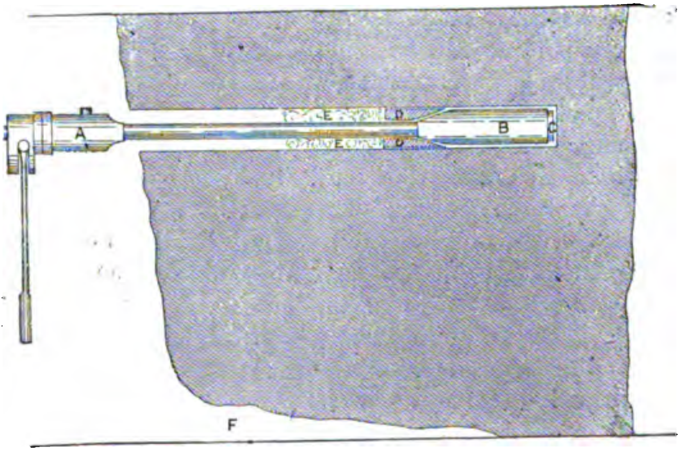


Fig. 101.

466. Have you had experience with any other wedge than the one described in question 464?

Yes; the author has had experiments made at the Aldridge Colliery, with Burnett's patent mining wedge. It is the most powerful wedge that has come under his notice, and can be made with sufficient expanding power to bring down any ordinary seam of coal. The following is a description of the working parts and the working of the wedge. For the illustrations, figs. 102, 103, 104, 105, 106, 107, 108, 109, the author is indebted to Mr. Burnett. Its action is by drawing a wedge, *a*, between a series of rollers, *b*, working against two feathers, *c c*, which have been previously pushed into a hole bored into the coal about 4 in. diameter. This wedge is a prolongation of a bar, *d*, terminating in a screw, *e*, which is sufficiently long to project some short distance clear of the hole. The feathers, *c*, are also prolonged by the rods, *f*, till they come outside the hole. These rods being riveted or otherwise secured to a short lever, *g*, terminate in a projecting pin at *g′*; *h* is a nut working on the screw, *e*, and kept in its place by the washer, *i*, made fast to the short lever, *g*, by four screws, *j*; *k k* are the two sides of a ratchet-lever enclosing between its jaws the ratchet-wheel, *k′*, and having attached to it a pawl, *l*, working on a pin, *m*, and kept in its place by a spring, *n*. The ratchet-wheel, *k′*, is screwed on to the nut, *h*, and made secure thereto, so that the nut will revolve with the ratchet-wheel. The sides of the ratchet-wheel, *k k*, are brought together and prolonged with an opening, *o*, cut in them. In this opening is introduced a short lever, *p*, which works on the pin, *g′*, and has a roller, *q*, working on pin, *r*. The end of this short lever, *p*, is made square at *s*, and to this square is attached the lever, *t*; *g′*, secured, as it is, by the two feathers, *c*, which are jammed fast in the hole, is immovable, and as a backward and forward motion is given to the lever, *t*, the roller, *p*, communicates it to the ratchet brace with its curiously-shaped opening, *o*, which allows the brace to go just sufficiently backwards and forwards to catch one tooth of the ratchet-wheel, and no more, at every double stroke. The ratchet-wheel being attached to the nut, *h*, acts on the screw, *e*, and pulls the wedge forward. The gain of power claimed for this wedge is such as to produce a bursting pressure of 5 tons for each pound force applied at the 2-foot lever. The screw is ⅝-in.

pitch; it is proposed not to exceed ½-in. pitch, by which the power will be increased to 6 tons per pound applied The improvements, which are themselves patented, in the "Improved" wedge are briefly as follow:—First, guides for rollers are now formed on the feathers, which are channelled for their reception, and are hence much stronger than in the original design, whilst, by the fact of the side plates being dispensed with, the simplicity of the machine is materially increased. Any number of rollers may be used; the one shown has four on each side, thus distributing the pressure more equally. Second, the compound lever is improved, making the ratio of leverage more uniform. The new arrangement is also self-contained and is very easily worked. The friction in working the "Improved" roller wedge is certainly much less than in any arrangement where wedges in sliding contact are used; in fact, the ease may be compared to drawing a heavy load in a properly-constructed carriage, as against dragging the same load along a surface in direct contact with it. It should be particularly noticed in the working of this wedge, that from the fact of the feathers being stationary, and the rollers in free contact with the wedge, the latter travels twice the distance of the rollers on the feathers. The mode of working may now be briefly described. The place is first "holed" to a depth of 3 ft. The wedge requires a hole to be drilled 4¼ in. diameter and 3 ft. 6 in. in depth, out of which 2 ft. 10 in. is taken up the full diameter, the wedge-bar projecting the remainder of the distance. This increased depth of 8 in. is not wasted, but is utilised for the next holing taken off. In places with two fast ends, both sides may be "nicked" to the same depth as the holing, and the hole drilled in the middle as near the top of the coal as possible; or the place may be nicked on one side only and the wedge-hole drilled near the fast end. In cases where coal is holed at the top, the wedge is, of course, applied at the bottom and exerts a lifting instead of a breaking-down pressure. After introducing the wedge into its hole, it is tightened into position by applying a suitable key to the nut, *h*. Next, the handle, *t*, is placed on the supplementary lever, *p*, which latter is provided with a roller, *q*, to diminish the friction, moving in a groove, *o*, in the ratchet-brace lever, *k*. It will rarely be necessary to drive the wedge quite home. The coal soon begins to crack, and it is desirable occasionally to intermit the process to give the coal time to work. When the coal falls, it breaks off at the full depth of holing, and the wedge falls down with it. The coal will usually come over in one large piece, which may break into several smaller pieces on striking the floor. Around the wedge-hole will be found a little small coal, the result of the crushing action of the wedge, the proportion of which will be less than 5 per cent. of the mass, all the rest being round coal.

467. Can you give a description and the mode of using lime cartridges for bringing down coal?

The cartridges consist of highly compressed caustic lime, and are about 3 in. or 3½ in. in diameter and of any desired length, made with a groove into which a small iron pipe can be inserted. The mode of using them is as follows:—The coal is holed or undercut in the usual way and supported by sprags or cockers. Holes are then drilled at suitable intervals near the roof; when the holes are drilled the cartridges are put in, a small pipe is inserted and the holes tamped or stemmed up to prevent the escape of steam; then a small force pump is attached to the pipe by means of a flexible india-rubber tube and water forced into the cartridge. The water is then shut off by means of a stop-cock fixed upon the out-end of the small pipe. Afterwards the tube is shifted until all the cartridges are charged with water. Part of the water is converted into steam and the lime expands and these two forces generate a sufficient force or power to bring down the coal in large blocks, the cockers being first removed.

468. State the comparative results of the lime cartridges against the ordinary system of wedging.

The following is extracted from a record of experiments made at the Shipley Collieries :—

Date. 1882.	Wedging.		Lime process.	
	Hours of labour.	Tons got.	Hours of labour.	Tons got.
Week ending Jan. 25	96¾	225	58	274
„ Feb. 1	100	178	71	236
„ Feb. 8	123	225	90	258
	319¾	628	219	768

140 tons more coal were thus got with 100 hours' less labour by the use of the lime patent than by wedging.

469. Can the lime cartridge be advantageously used in any seam of coal?

Yes; with a few exceptions, as where the coal is of a soft nature and intersected by a large number of what are termed "slips" or "faces," or in seams of coal giving off water in the shot-hole after it is bored; but even then the difficulty may be surmounted by placing the cartridge in an elastic waterproof tube. Taking into account the economical results compared with gunpowder, the author recommends the use of the lime cartridge for bringing down the coal in dusty mines, as it yields a much larger percentage of round coal, and there is absolute immunity from risk of explosion.

470. Does the use of the water cartridge ensure safety in blasting?

Yes; and I can quote no better authority than that of the Royal Commissioners on Accidents in Mines, who say "The so-called 'high' or violent explosive agents, which are represented by dynamite or gelatine-dynamite and by guncotton or tonite, can now be applied, not only for working economically in stone or shale, but also for coal-getting, by using them in conjunction with water according to one or other of the methods described in this report." Mr. James Macnab, who has had extensive experience with the water cartridge, and claims to be its original inventor, says that instead of dynamite or nitroglycerine compounds, tonite is undoubtedly the safest and best for general work, as it does not give off poisonous fumes (carbonic oxide) like pure guncotton, nor does its deteriorate like the latter on being stored.

471. Give a sketch of the best water cartridge that has come under your notice.

Fig. 110 is a sketch of Mr. Miles Settle's patent improved water cartridge. It is so contrived that the explosive is totally and equally surrounded by water in and under all conditions. The fuse is fired by electricity although it has been put to some of the most crucial tests—being, for example, exploded in a barrel of gunpowder, in

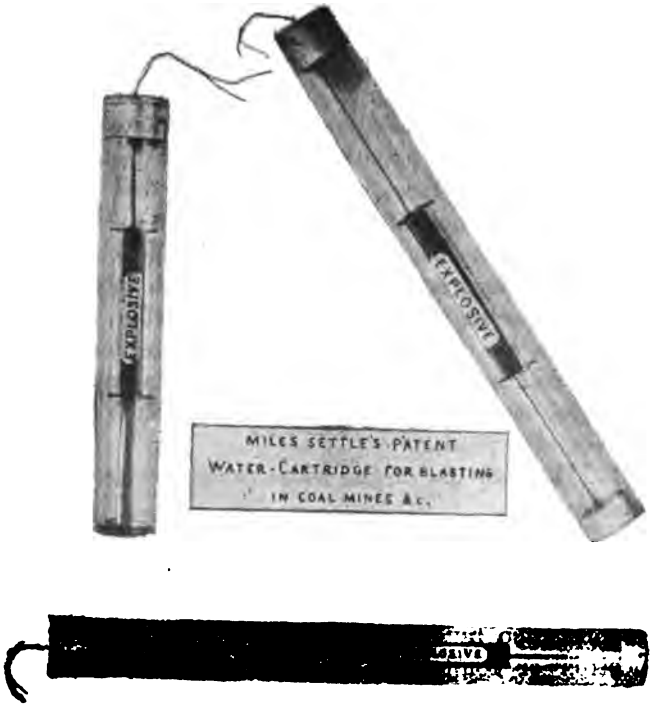


Fig. 110.

blown-out shots, in coaldust, &c.—no flame has been observed. The water cartridge is now successfully and extensively used in some of the most fiery and dusty mines. The author has adopted the cartridge at the collieries under his charge for the last two years, and can testify to its thorough efficiency and safety.

472. How would you charge your shots with gunpowder?

Clean all the dust out of the hole, put the powder to the back end, and place the fuse in, tamp it carefully with clay, light it with touch-paper or with a thin wire heated through the gauze of a lamp; then get far enough out of the way.

473. If your shot missed, what would you do?

Bore another hole by the side of it.

474. Can you describe Tangye's patent fuse for blasting purposes?

In this fuse the powder is enclosed in an impermeable solid-drawn metallic tube, which keeps it perfectly water and air tight. The tube is relieved of all strain by the use of longitudinal strands or threads, which impart great strength without impairing the flexibility and manageableness of the fuse. The external coating, if even soaked in water, does not prejudice the free burning of the powder; indeed, the fuse may be used in this way to minimise the production of smoke.

475. Why is it safer to use a copper or brass rammer for stemming shot-holes than an iron or steel one?

Because the power of absorption of heat is less in copper and brass than in iron or steel; a rammer of copper or brass is also more malleable and softer, and there is less danger when it comes in contact with other substances.

476. To ensure the greatest possible safety, what system would you adopt when firing shots in a seam of coal that gives off explosive gas?

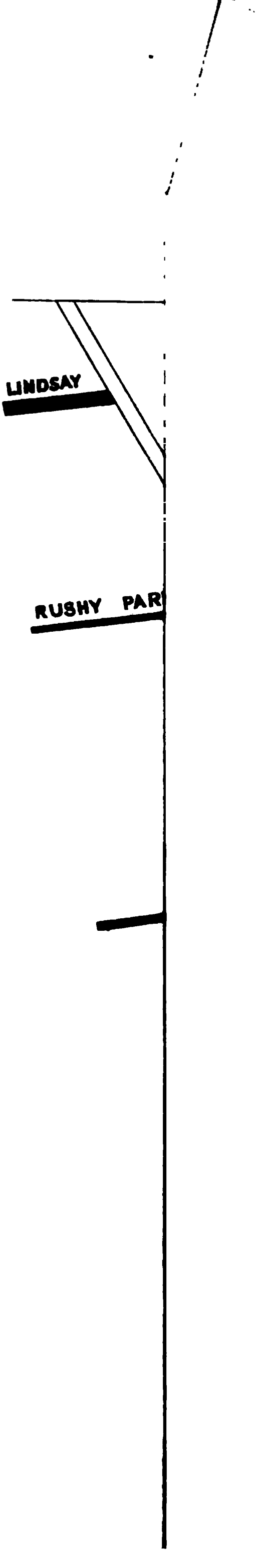
I should fire the shots at night, when all the men were out of the pit, commencing near the return airway, taking them in rotation, so that if gas were liberated by the first shot it would not have to pass the next one, but would go direct to the return airway, and the workings would thus also be kept free from powder smoke, &c. This system of shot-firing can be carried out better by the longwall system than by any other. Fewer shots are required in the longwall than by any other method of coal-getting.

477. A shaft is sunk to a seam of coal that lies at an inclination of 1 in 5, and at a short distance on the dip side of the shaft there is an upthrow fault of 70 yards; how would you win the coal lying between the shaft and the fault without driving an engine-brow down ?

I should sink the shaft a sufficient depth below the coal to enable me to drive a horizontal tunnel on the dip side which would strike the coal at the point where the fault cut it, as shown at A, fig. 111. The same thing would apply to the two seams higher up the shaft. By this method no machinery would be required to haul the coals up the brow nor to pump the water, which would run along the tunnel into the sump at the bottom of the shaft.

478. If you had shafts sunk to a seam of coal lying at an inclination of 1 in 3, and at some distance, say 600 yards, on the dip side of the shafts, there was an upthrow fault of 65 yards, how would you win the coal lying between the shafts and fault, and also on the opposite side of the fault, without driving an engine-brow down in each separate seam of coal ?

I should drive two horizontal tunnels as shown by dotted lines A B C (fig. 29), which is a section of a colliery recently under the author's charge. From point A; where we commenced, to point B, it will be seen that the tunnels intersect or cut seven different seams of coal, and on the rise side of the fault five others from B to C. It may be thought that it would have been more feasible to have sunk Nos. 3 and 4 pits down on the rise of the fault instead of driving the tunnels, but this was impracticable, for the


LINDSAY
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reason that the Yard and Birches seams had been worked, and were flooded with water. The pound of water in these seams extended two or three miles across the district. At first sight it may be thought that there would be an enormous outlay of capital in driving the tunnels from A to C, and that a large permanent expense would be incurred in hauling the coals from C to A, but the cost of driving the tunnels is trifling when the large area of coal recovered by them is taken into account and the small cost per yard paid for driving (£1 2s. for the main tunnel, and 18s. for the counter tunnel). The cost of hauling also with a complete system of endless rope haulage on a level road would be but little more per ton for a long distance than a short one, the haulage plant being once laid down.

479. Give a sketch of a good stopping or dam to prevent the water from getting into the workings where a district of a colliery gives off water, which is accumulating and is likely by its rise to stop other districts of the pit.

Figs. 112 and 113 are sketches of a good dam for such a purpose. It can be constructed to withstand any pressure or head of water. In selecting a place for these dams the ground should be as solid and free from cracks

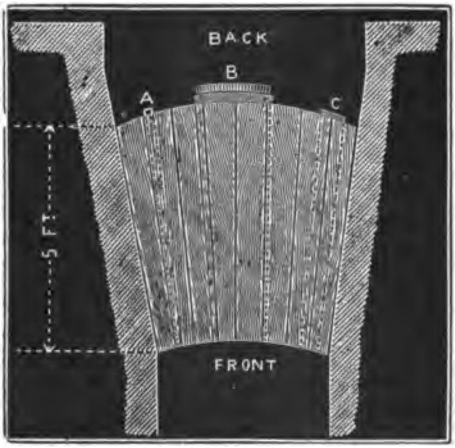

Fig. 112.

and breaks as possible, and the roof, floor and sides should be sheared wedge-shape. The dam illustrated is termed a frame dam, and is usually made of fir balks 9 in. square at the thick end, and tapered to 6 in. square at the thin end; it is generally 5 ft. or 6 ft. long, and placed as shown in sketches. A is a small pipe to allow all gas to escape until the water has risen and covered the whole area of the dam; it is then plugged. B is a round hole 18 in. in diameter for allowing the persons engaged in putting in the dam to pass out after it is completed. C is a pipe for water to run through while the dam is being built; the back of the dam is firmly wedged with hard wooden wedges. When the wedging is completed a plug is driven in the pipe C; the workmen then pass out through the hole B, drawing at the same time a large plug into the hole as they pass out. This plug is made taper, so that the greater the pressure of water at the back of the dam, the tighter the plug.

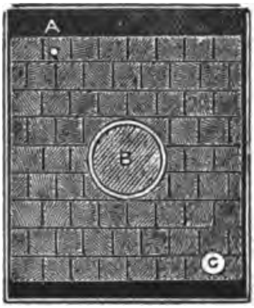

Fig. 113.

480. Produce a good plan of a pit-bottom arrangement, showing the number of lines of tram rails required for an estimated output of at least 500 tons per day raised at one pit.

Fig. 114 is a plan showing the position of the tram-rails with the walls of the shaft. With pit bottom so arranged there would be no difficulty in putting as large a quantity of coal in the cage as any winding engine would be able to raise. It will be seen that A A is a set of tram rails running at both sides of the shaft to allow loaded or empty tubs to pass or repass from one side to the other; B B is a line of rails on both sides of the pit to convey the empty tubs into the workings; C C C C are sets of tram lines to bring the loaded tubs from the workings to the pit bottom. These several lines of tram rails can be laid as far into the workings as circumstances will allow before they are connected together with points and crossings. D D are iron tram-plates to facilitate the motion of tubs from the end of the tram-rails into the cage.

As the form and section of rail and the manner of laying, materially affect the output of coal, attention should be given to these things. For all main horse roads and engine roads I would use steel T rails and steel sleepers the rails being fish-plated together in 12 ft. lengths. For the working face I would use bridge rails and steel sleepers. These rails are in 6 ft. lengths and not fish-plated, as they will be often laid and relaid. Messrs. Hipkins and Bickley, of Walsall, have patented a very excellent steel rivetless sleeper — which the author, from his own experience, can strongly recommend. In the patent steel rivetless sleeper the lips or jaws formed to hold the rail in position are stamped out of the solid plate and are stiffened by corrugations or brackets which are also raised from

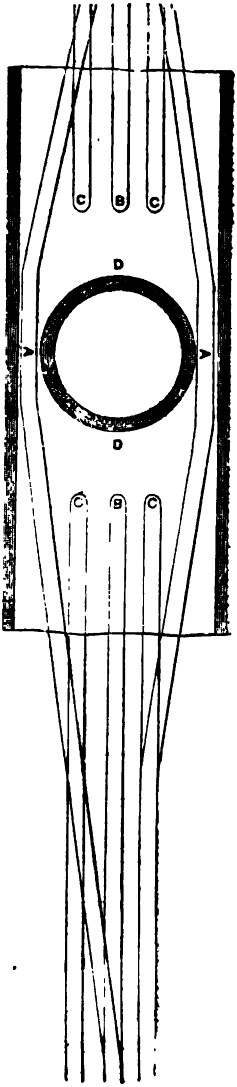

Fig. 114.

the solid plate out of the hollow at the back of each jaw; a centre strip is left in for the rail to rest upon as well as the metal at each side of the sleeper, thus dispensing with all rivets and loose parts, and forming a sleeper which will stand for many years and be uninjured by the roughest work. These sleepers are much stronger than the old iron ones, while, being turned down at the edge, they settle into the ground with great firmness, leaving very little likelihood of throwing the rails off, and in comparison with the old wood sleepers they require no nails for laying down. The steel sleepers can be made to fit any section of rail and any gauge of road.

481. Give a sketch of points and crossings for connecting three lines of tram rails, and switches and levers for turning the points of the same.

Fig. 115 is a sketch showing junction of three lines of tram rails which run into one and showing the crossings, points, switches, &c., and the position of the switch-box. Fig. 116 shows the position of the switch handles when they are opened and shut respectively with weights

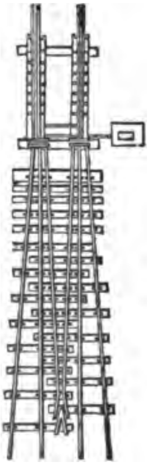

Fig. 115.

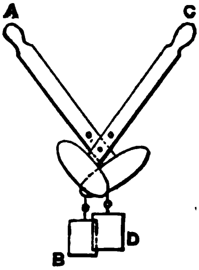

Fig. 116.

attached; when a set of points is shut, the switch handle and weight will be in the position shown at A B, and when open as shown at C D.

482. In approaching old and abandoned workings likely to contain an accumulation of water, what precautions would you take to guard against danger?

I should drive two drifts or headings in the direction in which the water would be likely to be met with. The form and dimensions of the headings would depend upon circumstances, but should never be more than 8 ft. in width. I should put at least three boreholes in the face of each heading, one in the centre and one on each side, about mid-way between the roof and floor, keeping the boreholes at least 5 yards ahead of the working face. The boreholes are generally 1½ in. diameter. (See fig. 117.)

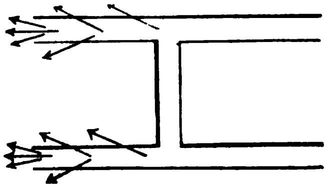

Fig. 117.

483. Give a short code of rules for the guidance of firemen when making their examinations?

The following is a short code of rules drawn up by the author and given to the firemen under him at the Rainford Collieries some years ago.

RULES FOR THE FIREMEN.

No............ Pit...................... Colliery Company Limited,
From...Manager,
To..Fireman.

(1.) Before decending the pit every morning you must enquire of the enginemen if the machinery has been examined for you to do so.

(2.) You must examine the barometer and thermometer and book what they stand at.

(3.) You must ascertain if the fan or furnace is working all right.

(4.) You must go down the pit with no other light than a locked safety lamp, and as you descend the shaft, notice the conductors, stays, walling, tubbing, sheeting and signal apparatus if they are all in working order.

(5.) Inspect the return airways with a locked safety lamp, and see if the ventilation is good and in its usual state.

(6.) Go with a locked safety lamp and examine all the air-crossings, regulators, doors, brattice, stoppings, working-places and roadways leading thereto, examine all cavities in the roof and open spaces in the goaves, &c., and see that means are adopted to prevent the stagnation of gas in such places, and if you find any danger from gas or any other source, you must not allow a man or boy to go there until the danger has been removed; take up two rails at the entrances of such places, and put them across the road with a danger signal or fire-board.

(7.) Make a true report of the result of your examination in the report book kept for that purpose. Then, if all is safe, signal for the men to descend.

This set of rules would require a little alteration if two shifts of men were employed.

484. Give a short code of rules for the guidance of shot-firers?

The following is a short code of rules drawn up by the author for the guidance of shot-firers.

RULES FOR THE SHOT-FIRER.

No.......... Pit........................... Colliery Company Limited.
From................................ Manager,
To.................................. Shot-lighter. No....... District.

(1.) Before firing any shot you must carefully examine the place where it is to be fired, with a locked safety lamp, and should you discover any noxious gas, or any defects in the roof, or any danger from any other source, no shots must be fired until the danger is removed.

(2.) You must return immediately to each shot after it fires, and if you find the shot has lighted a blower of gas, or liberated a quantity of gas, or disturbed the roof, so as to cause danger, you must immediately extinguish such blower of gas and withdraw the men out of the place until the danger is removed.

(3.) You must not fire any shot until the coal is holed under and cut on the one side.........feet.........inches.

(4.) You must not fire any shot where the shot-hole is bored on "fast or solid."

(5.) You must not allow any shot to be unrammed after it has mis-fired.

(6.) All powder that is in the pit must be made up in cartridges, and you must see that no workman has in his possession more than 5 lb. at any one time.

(7.) You must see that there are no steel or iron pickers in use by any workman, nor in their possession; copper or wooden rammers, or "copper prickers," must be used exclusively.

(8.) If, at any time, either before or after you fire a shot, you find that any timber requires setting or drawing, you must not leave the place until such requirements are duly executed.

(9.) You must see that the workmen set sufficient holing props, and do their work in a safe and proper manner.

(10.) You must see that the workmen draw all timber, both whole and broken, out of the gob.

(11.) You must keep all openings or thirlings bricked up, and your brattice as close to the face as practicable.

(12.) You must see to the coal coming out of your district as far as you possibly can, but not to neglect the safety of the men for this.

(13.) Should there at any time anything arise beyond the scope of your authority, you must immediately report the same to your superior officer.

(14.) It is also your duty to make yourself acquainted with the special and general rules in force at the colliery.

Many explosions and other accidents would be prevented if each manager were to draw up a set of rules suitable to his own collieries for the firemen and shot-firers.

APPENDIX TO CHAPTER VIII.

STANLEY'S PATENT COAL-HEADING MACHINE.

Mr. R. Stanley, of Nuneaton, has invented a machine for driving coal-headings. The machine is worked by compressed air. The illustration (fig. 118) and the simplicity of construction render much explanation of the machine unnecessary. It is made to cut an annular groove around the face of the heading, leaving a core which either falls or is got off as the work proceeds; it is not then run back, the coal being passed back alongside of it and loaded into tubs in the usual manner.

The machine-frame is made to advance at will by the propelling cog wheels. The propelling gear consists of a cog wheel having a screw-threaded brass bush fitted into its boss, which works in the threaded part of the central shaft. This is held to the frame and driven from a sliding cog on the crank shaft, when the cutting gear is thrown out, and, this set in motion, the frame is caused to advance on the shaft (to advance it the full length requires less than a minute), or the shaft is caused to retire in the frame, according to which of the two parts of the machine is fixed in the heading. The direction of the machine is thus kept between the cuts, and all is ready for cutting as soon as the screw pins are fixed. The cog wheel with threaded bush is held to the frame; and, as the cutting proceeds, being prevented from turning the central shaft, is caused to advance in the frame.

The manner of working is as follows:—The machine being up to the face of the heading and fixed ready for work, one man takes his place at the left side with a raker, and as the cuttings are brought back by the scrapers, easily rakes them towards him as the arms are revolving, passing them to the man at the back as opportunity presents itself. When the arms have advanced sufficiently to allow of it, he moves from the left to the right side of the machine in front of the cylinders; and, changing his

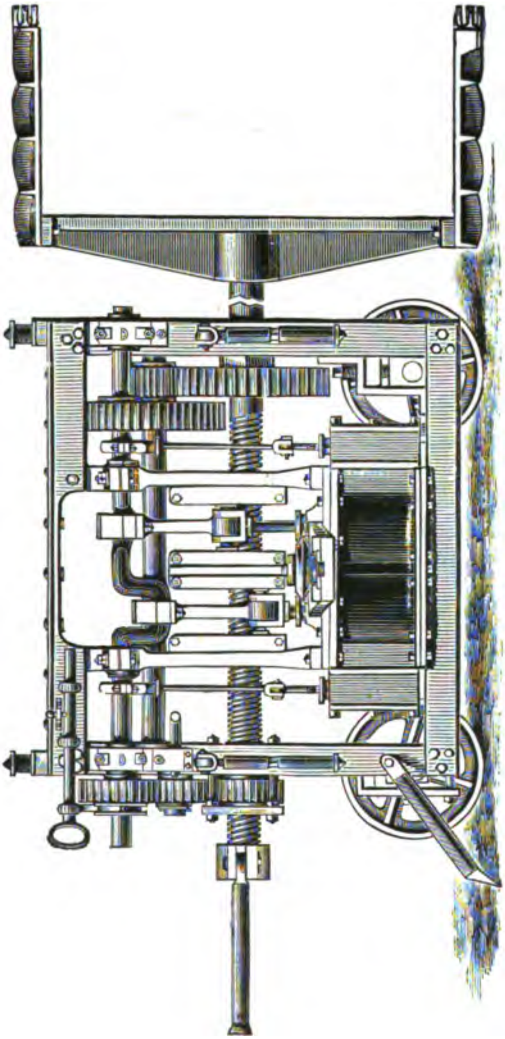

Fig. 118

raker for a shovel, throws the cuttings along the left side, to the back of the machine, where the man at the handle loads them into a tub or throws them still further clear of the machine. Small lumps that fall from the face whilst the cutting is proceeding, are dealt with in the same manner without stopping the arms, but for big lumps, or when the core breaks down (which occurs ordinarily within a distance of a foot or so), the air is shut off whilst the coal is disposed of. If men mean work this is soon done, and upon the energy displayed at this point depends to a great extent the distance cut, for the machine does not take long to do its part of the work. The arms having worked out their full length (between three and four feet), the engines are stopped, screw pins slacked, the propelling wheels are put in gear, and the frame is run forward and fixed for another cutting.

The time occupied in doing this varies from 5 to 10 minutes. Of course the speed at which headings can be driven by the machine varies according to circumstances, but, on an average, it will be found to be about four times that of hand labour. Not the least recommendation of the machine is that it gets the coal in solid blocks, in the shape of millstones. The author can speak confidently of the merits of this machine. On Saturday, October 6th, 1888, by the kind invitation of Mr. R. Stanley, he paid a visit to the Nuneaton Colliery and there saw the coal-heading machine in full operation, and was highly gratified with the way the machine did its work, and the great amount of heading it would penetrate compared with hand labour. It is a good practical invention and sure of success. Messrs. Stanley have already supplied many of their machines to mines at home and abroad. The following is a tabulated statement of results of work :—

TRIALS OF MESSRS. STANLEY'S HEADING MACHINES ON THE OCCASION OF THE VISIT OF THE CHESTERFIELD AND MIDLAND COUNTIES' INSTITUTE OF ENGINEERS.

August 30, 1888.

Time.			Distance cut.	Interval for breaking Core and removing Coal and Slack.	Remarks.
Machine started.	Machine stopped.	Duration of cutting.			
H. M.	H. M.	H. M.	FT. IN.	H. M.	
10 34	10 38	0 4	0 11	0 4	*No.* 1 *Machine.*—Core-cutting type for circular heading 5 ft. 4 in. diameter, core 5 ft. Time occupied in cutting a distance of 3 ft. M. 17½ Time occupied in breaking core; removing coal and slack, and preparing to start Machine for another cut 20
10 42	10 42	0 4½	0 6½	0 2	
10 48½	10 49¼	0 ¾	0 2	0 6	
10 55½	11 3¾	0 8¼	1 4½	0 8	
		0 17½	3 0	0 20	Total 37½
11 11¾					Machine started for next cutting after having been moved forward.
11 31	11 35	0 4	1 2¼		*No.* 2 *Machine.*—Core-cutting type for circular heading 5 ft. 4 in., core 5 ft. Time occupied in cutting a distance of 2 ft. 9¾ in. ... ... M. 11½ Time occupied in breaking core, removing coal and slack, and preparing to start Machine for another cut 33½
	11 38	0 3	0 6½	0 14½	
11 52½	11 57	0 4½	1 1	0 19	
		0 11½	2 9¾	0 33½	Total 45 The core in this heading was hard and dead, requiring wedging to remove, owing to the 7 ft. seam having been worked out below it. Machine re-started after having been moved forward for another cut.
12 16					
12 47	12 55	0 8	1 3		*No.* 3 *Machine.*—New type cutting away all coal from face and delivering to back of Machine mechanically. 4 ft. circular heading. Cut 15 in. and delivered the slack to back of Machine in eight minutes.

(Signed) GEORGE SPENCER.

CHAPTER IX.

SAFETY LAMPS AND THE LIGHTING OF MINES.

[THE ILLUSTRATIONS ARE INSERTED AT THE END OF CHAPTER.]

For questions 485 to 536, with the illustrative drawings, the author is to a great extent indebted to Mr. James Ashworth, a gentleman of large experience, whose name has been prominently before the mining world in connection with safety lamp tests and experiments. Mr. Ashworth has himself also made improvements in the safety lamp which have received the recommendation of the Royal Commission on Accidents in Mines.

485. What is meant by a "safety lamp"?

A lamp which is so protected by coverings as to prevent carburetted hydrogen, when ignited or exploded by the lighted wick within, communicating its flame to the outer atmosphere.

486. In what year was the protection of a naked light in a coalmine found to be necessary, and why?

In 1710, when the first explosion of firedamp occurred in Belgium.

487. What were the earliest recorded modes of lighting fiery mines in safety?

Firstly, by putrescent fish skins, which produced a weak phosphorescent light. Secondly, by the flint and steel mill invented by Spedding, of Whitehaven, in 1760.

488. Why were these discarded?

Because fish skins were found to be expensive and inefficient, and the "steel mill" unsafe and so costly that at one colliery its maintenance cost the company £40 per week.

489. Who invented the first safety lamp?

Wyndus is said to have invented a safety lamp in 1684, and Humboldt about 1750, but no description of the construction of either of these lamps has been discovered. Dr. William Reid Clanny, in 1813, invented his first safety lamp (figs. 119 and 120), which was tested in the Herrington Mill Pit in 1815, but never came into general use. In 1815 Sir Humphry Davy invented three lamps called the "safe," the "blowing," and the "piston." The one called the "safe" was put into use at Hebburn Colliery on the 1st of January, 1816. Sir H. Davy patented another lamp in which the inlet and outlet air passed through a series of metal tubes, and he afterwards improved this by adopting a brass cylinder in which were a number of apertures covered with wire gauze in place of the outlet vertical tubes. In 1816 Sir H. Davy constructed the lamp which is known all over the world as the Davy lamp. (Figs. 121 and 122.)

490. What other lamp was invented about this time?

The Stephenson (fig. 123), invented by George Stephenson, November 30, 1815. This was the third lamp he invented. It consisted of a glass chimney surmounted by a copper cap full of small holes, surrounded by a copper cylinder perforated with large holes, and the air necessary for the combustion of the flame entered through small tubes at the base of the lamp.

491. Can you give a detailed sketch of the original Stephenson lamp?

Figs. 124 and 125 are sketches of the original Stephenson lamp with all details marked upon them.

492. Have any of the original inventors received public rewards in recognition of their discoveries?

Yes. Sir H. Davy was publicly thanked and presented with £2,000 worth of plate, and George Stephenson with a silver tankard and the balance out of £1,000, which was handed to him in cash at a meeting in Newcastle-on-Tyne in 1818.

493. What is the most important part of a safety lamp?

The gauze.

494. Who discovered the value of gauze for the interception of flame?

Sir H. Davy, in following up Mr. Tennant, who noticed, in his *Researches on Flame*, that burning gases would not pass through tubes of a certain diameter, further discovered that flame would not pass through a great many apertures when their depth was equal to their diameter, and hence that it would not pass through a fine wire gauze. With tubes he found that the flame of an explosive mixture would pass through a glass tube of $\frac{1}{4}$ in. in diameter and 1 ft. long in under two seconds, but not through one of $\frac{1}{7}$ in. in diameter; and again, that an explosion would pass through a tube $\frac{1}{28}$ in. in diameter by 2 in. long, whereas a metallic tissue, however fine and thin, if the apertures filled more space than the cooling surface, offered a perfect barrier to an explosion.

495. By what reasoning and experiments did Sir Humphry Davy fix the most suitable size of wire and mesh for a safety lamp gauze?

He found that the ratio of combustibility of the different gaseous matters is, to a certain extent, as the masses of the heated matter required to inflame them. Thus, an iron wire of $\frac{1}{4}$ in. in diameter heated to a cherry red, will not inflame olefiant gas, but it will inflame hydrogen gas; and a wire $\frac{1}{8}$ in. in diameter, heated to the same degree, will inflame olefiant gas; but a wire of $\frac{1}{500}$ in. in diameter must be heated to whiteness to inflame hydrogen, though at a lower heat it will inflame bi-phosphuretted hydrogen gas; but a wire of $\frac{1}{40}$ in. in diameter, heated even to whiteness, will not inflame mixtures of firedamp and air. A tissue which would not intercept the flame of hydrogen when red hot, will still intercept that of olefiant gas; and a heated tissue which would communicate explosion from a mixture of olefiant gas and air, will stop an explosion from a mixture of firedamp or carburetted hydrogen. Thus, he also found that a wire gauze composed of wire $\frac{1}{40}$ in. to $\frac{1}{60}$ in. in diameter, and containing twenty-eight wires or 784 apertures to the square inch, made into a cylinder and surrounding a light, when plunged into an explosive atmosphere became quietly and gradually filled with flame without any explosion being caused, and was safe in atmospheres of this kind. Therefore this material, constructed as just described, was adopted for use in coalmines in January 1816, and has been in use ever since.

496. Have these conclusions stood the test of time?

Yes; but on the Continent smaller wire, with more meshes per square inch, has been most generally adopted.

497. Have any modern experimenters attempted to prove the correctness of Sir H. Davy's conclusions?

Yes; M. Marsaut, who concluded that the English gauze is firm and satisfactory, that too fine wire is objectionable, whilst the predominating influence with regard to resistance is that of the size of the mesh; thus, a gauze with wire of $\frac{1}{100}$ in. diameter and 1,740 apertures per square inch gave more resistance than one with wire $\frac{1}{60}$ in. diameter and 784 apertures per square inch.

498. Would wire made of some other metal than iron be more suitable for the construction of safety lamp gauzes?

Yes, if less easily corroded by the atmosphere, and equally as strong as iron.

499. Is there any standard size or shape to guide us in the construction of safety lamp gauzes, and have any investigations been made to ascertain what is the safest size and shape?

There is no standard size or shape of gauze. M. Marsaut and the Prussian Firedamp Commission are the only experimenters who have investigated this question in a practical way. M. Marsaut found the shape to be of special importance, and that a gauze with nearly parallel sides of 1½ in. diameter by 3½ to 4 in. high (Davy) was quite safe in a quiescent explosive atmosphere, but a gauze of truncated conical form 1·8 in. diameter at the top, 1 in. diameter at the base, and 4½ in. high passed the explosive flame at every trial, whilst a gauze of the same height, 1 in. diameter at the top and 1·8 in. diameter at the base resisted every trial. (See figs. 126, 127, 128.) To prevent exterior explosions M. Marsaut decided that it is necessary to maintain a definite relation between the volume confined in the lamp, and the surface open for the burnt gases resulting from the explosion. These conclusions are supported by the Prussian Firedamp Commissioners, who, whilst acknowledging the safety of the 1½ in. diameter cylindrical Davy gauze, decided that the conical form described above is the best, and that a partial covering of the wire gauze considerably increases the liability to explosion, especially when it concerns the lower part, and that any obstructing of the top tends to lessen its safety. (See figs. 129, 130.)

500. There being no standard size of gauze or mesh, give the names of a few varieties of the Davy lamp.

Ordinary Davy	Fig.	121
Fireman's „	„	122
Scotch gauze	„	131
French Davy (Gard district)	„	132
Struvé „	„	133
Pieler „	„	134

501. Has the Davy lamp proved to be perfectly safe in use?

No, but it has been the means of opening up fiery mines, which otherwise would not have been worked at all.

502. Has the Stephenson lamp proved to be safer than the Davy, and does it give as good a light?

Under some conditions, the wick flame and ignited gas being automatically extinguished, the Stephenson is safer than the Davy, but it does not give such a good light.

503. Has the Stephenson lamp been so far improved as to give increased safety and lighting power? If so, name the improvements.

Yes; for instance, the

Bainbridge ...	(Fig. 135),	Lighting	power	only.
Williamson ...	(„ 136),	„	„	and safety.
William Purdy	(„ 137),	„	„	„
Hann............	(„ 138),	Safety.		

504. What is the difference between a Davy and a Stephenson lamp as now constructed?

The long glass cylinder and perforated metal cap of the original Stephenson is covered by a large cylindrical gauze, and the air enters through small perforations in the frame of the lamp, then through the lower part of the gauze cylinder and below the glass to the wick flame (fig. 123).

505. Did Sir Humphry Davy consider his lamp to be perfect; and, if not, did he recommend any addition to it?

No; he recommended the addition of a shield to protect it from the effects of strong air-currents.

506. What was the first alteration in the construction of the Davy lamp to protect it from strong air-currents?

The glass cylinder of the Clanny lamp, which by replacing part of the gauze gave protection to the wick flame and increased its photometric value.

507. What other important additions have been made to the Davy lamp?

The protection of the entire gauze by a shield or shields. For instance:—

Upton and Roberts (fig. 139), protected by a circular glass opposite the wick flame, surmounted by a brass cylinder, and with the air inlet somewhat like the Stephenson. This was the first lamp which was *completely* shielded.

Routledge and Johnson's double combination lamp (fig. 140) is similar to the Upton and Roberts, but the air inlet is *above* the flame.

Knowles Davy (fig. 141) varies from the Upton and Roberts in a similar way, with the addition of a gauze disc at the top of the metal shield.

Ayton (fig. 142) is a Davy placed within a shielded Clanny, with the Stephenson type of air inlet.

Jack Davy has a circular glass shield outside the gauze. Fig. 143 shows the safest construction of the plain form of this lamp.

Mercier's Jack Davy (fig. 144) is a shielded form of fig. 143, and constructed for the use of shot-lighters in mines with a strong air-current.

Tin Can Davy (fig. 145) is a very simple and safe form of shield, the lamp being merely placed inside the tin can or case.

Donald and Laidler patent Davy lamps (figs. 146, 147, 148 and 149) are very similar in their outward appearance and belong to the Tin Can type of safety lamp, from which they differ only in their more convenient form for cleaning and locking. The Laidler is locked by Laidler's patent cam lead lock. The Donald is locked by Ryder's pillar lock. The Laidler is also furnished with a patent extinguisher for oil or spirit lamps, which is fully described on the drawings.

508. Give the names of the best known Continental forms of the Clanny lamp.

The Boty (fig. 150) and the Westphalian (fig. 151), which are nearly alike in construction, the air entering below the flame. The Boty is generally made like the English Clanny, but the gauze is of larger diameter.

509. Has the Clanny proved to be any safer than the Davy or Stephenson.

No, but the type has received so much attention from safety lamp inventors, that it now holds the premier position as a workman's lamp, both as regards light and safety.

510. Give a list and description of some of the improved Clannys.

Daglish and Flood's, No. 2.—Gauze protected by brass cylinder, reported by the North of England Institute Lamp Committee, 1867, as quite safe up to a velocity of 35 ft. per second.

Lindsay Wood or Mining Institute lamp.—A small cylindrical gauze, which reaches only to a little below the top of the glass cylinder, is placed inside a Clanny lamp.

Eloin (fig. 152).—The inlet for air is below the flame, and is shielded, and a metal cylinder and gauze disc replace the ordinary gauze. Too sensitive for use.

Pelton (fig. 153).—Double shields inside the gauze. The outer shield is pierced with rows of small holes corresponding to the corrugations of the inner shield.

Ashworth (figs. 154, 155 and 156).—Correspond to the Nos. 17, 19 and 4 of the Accidents in Mines report, and are single-gauze shielded lamps. Fig. 157 has a conical glass, and very small cubic contents. Compare with fig. 158.

Marsaut, three gauzes (fig. 159).—A shielded Clanny, with three conical-shaped gauzes. Fig. 158 has two gauzes only.

Birckel (fig. 160).—Shielded Clanny, fitted with "shut-off."

Evan Evans (fig. 161).—A double-shielded Clanny, with automatic "shut-off."

Evan Thomas (fig. 162).—Shielded Clanny, No. 7 of the Accidents in Mines report.

Thomson (fig. 163).—Shielded Clanny, with chimney and double cylindrical glasses.

Routledge and Johnson (fig. 164).—Double combination of the Clanny and Mueseler, with outer shield.

511. What other lamp is there which is considered a typical lamp? Describe it.

The Mueseler (fig. 165), named after its inventor, who fitted within a Clanny lamp a conical-shaped chimney, supported by a horizontal diaphragm of gauze directly on the top of the glass cylinder.

512. Has the Mueseler type of lamp proved to be safer than the Davy, Stephenson or Clanny, and has it been improved upon; and, if so, by whom?

It has proved to be safer, and its use is compulsory in Belgium. Many improvements have been made in its construction to obtain increased safety, more light, to protect it from strong air-currents and dust, and to render it less liable to become extinguished when thrown on one side.

Mueseler Joassin, No. 1 (fig. 166).
Do. Demanet (fig. 167).—Increased resistance of horizontal gauze by the addition of a conical gauze.
Do. Joassin, No. 2 (fig. 168).
Do. Godin G (fig. 169).—The wick flame is surrounded by a conical gauze attached to the base of the chimney.
Do. Arnould No. 1 (fig. 170).—The chimney consists of two truncated cones joined at their small ends and with a disc of gauze within the chimney.
Do. Arnould No. 2 (fig. 171).—Similar to No. 1, but with the addition of a small Mueseler chimney inside.
Do. Arnould-Godin (fig. 172).—Part of the conical gauze of the Godin G is replaced by a conical glass.
Do. Morison (fig. 173).—The chimney is similar to the Arnould No. 1, with double cylindrical glasses, the air passing between them.
Do. English (fig. 174).—This lamp is remarkable as differing from the standard Belgian dimensions in the chimney, and is safer.
Do. Ashworth (fig. 175).—Similar to the above, with the addition of shields to the chimney and horizontal gauze.
Do. Mercier (fig. 176). . A shielded lamp, with the air entering at the top of the shield.

Mueseler McKinless (fig. 177).—A lamp in which the gauze is replaced by metal perforated with small holes.

Do. Smethurst (fig. 178).—Shielded Belgian Mueseler.

Do. Ashworth-Woolrych (fig. 179).—Double-shielded. Chimney is replaced by a small cylindrical gauze, with a reflector at the base.

Do. Green (fig. 180).—Partly shielded, with a small tin arm attached to the chimney under the diaphragm designed to extinguish the ignited gas by preventing its rotation.

Mueseler, Bryham's (fig. 181).—The top of the chimney protected by small gauze cylinder and double glasses.

Do. Evan Thomas (fig. 182).—Chimney similar to Arnould No. 2, double glass, similar to the Arnould Godin. No cylindrical gauze.

Do. Morgan (figs. 183, 184).—Many-shielded lamps, with three somewhat conical gauzes. The outlet of the chimney is thoroughly protected.

Do. Marshall (fig. 185).—A heavy double glass lamp, with an automatic "shut-off."

Do. Combes (fig. 186).—Very large glass cylinder. An unsafe lamp.

Do. Cosset Dubrulle (fig. 187).—Short chimney for use at pit bottoms.

Do. Clifford (fig. 188).—The peculiarities of this lamp are—a double skin of metal in place of the usual cylinder of wire gauze, a glass chimney connected with an internal flue of metal with a gauze inside it, and a cap or ventilator covering the outlet. The inlet and outlet are protected against violent wind by means of ports at or nearly at a tangent to the circular plan of lamp, entering into annular chambers with other ports or openings in their inner wall. The gauzes are round plates of perforated metal; at inlet they leave a hole in the centre for chimney to pass through; at outlet they are simply discs of same material, fitting into an arbour. In the modified lamp (fig. 188) there is direct communication between inlet and outlet through the skins. The lamp is furnished with the inventor's fusible-faced gauze, which, when gas burns within the lamp, melts and cuts off the supply, but does not fuse under the ordinary burning. It will be seen from the illustration that the tangential ports, both at the outlet and inlet, are usually in two rows and reversed in their direction. The force of a wind entering by the lower rows is diminished or destroyed by that of one entering by the upper row, and *vice versâ*. The construction of inlet and outlet chambers being identical, the suction at one neutralises that at the other, so that without regard to velocity of surrounding air, only so much air enters the lamp as is due to rarefaction by the wick-flame, and by the construction of the lamp, any excess of combustion beyond that of the wick-flame provides the means of its own extinction.

Mueseler Ashworth with gas-testing shutter (fig. 189).—This lamp has the double-shield arrangement of the same inventor's No. 4.—The metal chimney of the ordinary Mueseler is replaced by a chimney composed of a short and slightly conical metal base, to which a gauze cylinder of small diameter and a conical or horizontal gauze are attached in the ordinary way. The inner shield protects the lamp from all currents across the gauzes, and its conical outlet regulates the quantity of air passing through the lamp; consequently the lamp has withstood tests of upwards of 100 ft. per second of explosive mixture without failure. Over the inlet holes, above the glass, there is a movable shutter ring (see Howat's patent gas-testing lamp), which, when testing for firedamp, is moved so as to close the ordinary inlet holes, and to compel the whole of the air supply to enter by the holes at the top of the shield. The lamp is raised without lowering the wick-flame, until the spiring up of the latter indicates the presence of gas, or the lamp reaches the roof or highest part of the working. As soon as the spiring up of the flame indicates gas, the shutter is opened by the thumb or forefinger of the hand which holds the lamp, and the supply of gas is at once arrested and cut off and the light saved for further tests.

Mueseler Aldwarke.—This lamp consists of a chimney of the following dimensions:—Total height 100 mm., projecting below the horizontal gauze to a depth of 10 mm. (this part is not bell-mouthed). The diameter of the top of the chimney is 11 mm., and that of the bottom 31 mm. The chimney is made of cast brass, and is held up in the ordinary way by the horizontal gauze disc, which is firmly secured between a shouldering on the chimney and a nut which screws round the chimney. The circumference of the disc fits inside a flanged brass ring which takes the place of the copper ring usually forming the base of the ordinary make of outer gauze, and it is firmly secured in position by another ring which screws inside the first ring. The object of this is to prevent air or gas entering the combustion chamber, excepting through the horizontal ring and in its legitimate direction. Mueseler lamps furnished with this chimney have successfully withstood very high experimental tests.

513. What other types of safety lamp can you describe which are modifications of those already explained?

First, the Eloin type, in which the cylindrical gauze of the Clanny and Mueseler lamps are replaced wholly or in part by a cylinder of metal. For instance—

Eloin Clanny (fig. 152.)
„ Mueseler (fig. 190.) } Both these lamps are so sensitive to movement as to be useless for workmen.

Godin H „ (fig. 191.) Burns badly.

Gray (fig. 192.) This is a very good lamp. The air enters at the top of the lamp down four tubes and through a strip of gauze, the products of combustion passing up the cylindrical chimney in which two truncated cones are inserted to avoid the down currents to which all cylindrical chimneys are liable.

Fumat No. 2 (fig. 193).—Bottom shield obstructs the light. In the new Fumat lamp all the inlet and outlet holes are placed horizontally and are on the front side of the lamp only. The inlet gauze is thoroughly shielded and the air is brought from above to below the glass by a trunk-pipe, occupying about one-third the circumference of the lamp.

Second, the tubular chimney type. One of the lamps invented by Sir H. Davy previous to the Davy was of this type, as also was one of the Eloin class. The following are the best known of this type:—

Mueseler Joassin, No. 2 (fig. 194.)—Four small tubes of about 2 in. long form the top of the Mueseler chimney.

The Howat (fig. 195). The air enters through tubes in the bottom of lamp and passes out through a bundle of tubes covered by a circular gauze disc. Fig. 196 is another variety of this lamp.

The Howat Deflector lamp (fig. 197), one of the best known of this type, has placed inside the outer shield an arrangement of plates by which the whole of the air entering the lamp in the ordinary way is forced into the combustion chamber instead of partly escaping through the gauze without entering the combustion chamber. This forced draught has not been proved to reduce the safety of the lamp, but undoubtedly it greatly improves the lighting power, and is in extensive use. This type of lamp has been adapted to gas-testing purposes by adding a trumpet-like inlet by which the air of the mine enters the lamp from close to the roof, the ordinary inlet holes being closed by a patent movable shutter.

514. Describe Ashworth's patent Hepplewhite-Gray deputy safety lamp, and the principles of its construction.

This lamp (fig. 198), the original Gray, consists of four inlet tubes which also fulfil the duties of the standard of ordinary safety lamps, and hold the several sections apart. The air on entering passes through a movable plate called the "shut-off," thence down the four tubes and into the combustion chamber through the bottom gauze or sieve ring—which is made with a solid cylindrical side, in which a groove is cut in the outer circumference and holes bored through from the bottom of the groove. The outer circumference is covered by gauze, this forming an annular space between the gauze and the holes, thus gaining a larger area of gauze for the inlet air without increasing the size of the ring, and so obtaining a better protection for the glass, making the extinction of the wick flame and gas more certain when the latter explodes within the lamp (that is, when the gas-testing arrangement is not in use). The combustion chamber is a truncated conical glass, the shape of which gives great strength and better combustion. Above the glass is a slightly conical gauze, fitted at its base with copper rings flanged to fit the top of the glass, and surrounded and protected by a cylindrical shield with a conical outlet, which is, in effect, a Mueseler chimney. This outlet, as well as the inlet openings, is thoroughly protected by a hood of novel construction. The "shut-off" is a circular plate which revolves or screws on the top frame of the lamp, and closes all the inlet holes at once, and when put into action immediately extinguishes all flame within the lamp. One or more holes are cut near the base of one or more of the inlet tubes or through the lamp frame, and are covered by movable shutters which regulate the admission of fresh air to the wick flame, independently of the ordinary course of the ventilating current of air within the lamp. The fireman or official controls the whole lamp with one hand only when making a test for firedamp, using the thumb and forefinger to regulate the admission of fresh air where the tube slides are used, and one finger or thumb where the other arrangements are adopted. When the fireman commences to test, he pushes up one or both the shutters and raises his lamp in the ordinary way, but without lowering the wick flame, until the spiring-up or elongation of the flame indicates the presence of gas, or the lamp reaches the highest part of the mine without an indication. At this point the holes are gradually closed, and if any small percentage of gas is present it will be indicated as before described. A lamp suitable for overmen and firemen should be able to detect 2 per cent. or even a less percentage of firedamp with certainty, and this Mr. Ashworth claims his lamp will do.

515. Name some lamps which are constructed to extinguish the light if either of the glasses should break, or gas ignites within the lamp.

The Timmis, a lamp on the Eloin principle; the air enters at the bottom of the lamp. Two cylindrical glasses surround the flame, and the annular space between them is closed so as to be air-tight, and the air within is compressed by a condensing syringe, and distends a membrane at the bottom. When the pressure is removed, a spring forces up a tube round the wick flame, and thereby extinguishes it. The Ballardie; this lamp burns heavy petroleum oil, and when gas burns at the inlet holes a thread is burnt through, releasing a shut-off arrangement which closes the inlet holes. The Marshall (fig. 185); a heavy and expensive lamp, with double glasses. When gas burns at the inlet holes below the inside glass a thread loop is burnt through, releasing a spring which closes a cap over the outlet of the chimney. The Evan Evans (fig. 161); this is more simple and effectual than either of the foregoing, but is set in motion in the same way, that is, by the burning of a thread loop against the inlet, which, releasing a spring, closes both the inlet and outlet openings at the same time.

516. Glass having generally been adopted for surrounding the flame of a safety lamp, is it necessary to observe anything in the construction of the lamp at the point where the connection between the glass and the superposed gauze is made?

Yes; and M. Marsaut has clearly proved that the base of the gauze should be of the same diameter as the inside of the glass cylinder. (See figs. 126 and 127.)

517. What condition does the glass or muffled part of a safety lamp represent when explosive gas is fired within it?

That of the discharge of a cannon.

518. How is this to be neutralised?

By keeping the dimensions as small as possible and by fixing the top of the wick-tube as high up as convenient without obstructing the light, so that the neutral space below the flame, being filled with air may act as a cushion and thus reduce the pressure of the explosion on the surface of the gauze.

519. With the latter conclusion in view, where ought the air necessary to support combustion to enter the lamp?

Above the flame.

520. Generally speaking, are the lamps with their air supply entering above the flame as safe as those with it entering below the flame? Give examples.

Yes, safer, and usually give a superior light. For instance, the Ashworth Shielded Clannys (figs. 154, 155, 156, 157); the Evan Evans (fig. 161); the Marsaut (fig. 164, 158); shielded Mueseler (fig. 178); the Morgan (figs. 183, 184), The Evan Thomas (figs. 162, 182) are classed higher in these respects by M. Marsaut and the English Mines Accident Commission than the Bainbridge (fig. 135), the Fumat (fig. 193), the Howat (figs. 195 and 196) the Stephenson (fig. 123), the Williamson (fig. 136), the Westphalian Clanny (fig. 151). The principal arguments against lamps in which the air enters below the flame, are: (1) A smaller proportion of inflammable gas suffices to render a gaseous mixture just explosive or self-combustible when the ignition proceeds from below upwards than if the zone of combustion has to travel in the opposite direction. Mr. E. H. T. Liveing noticed this fact, and on taking two vessels 4 in. in diameter, filled with the same gaseous mixture, one provided with a platinum wire across the lower part, and the other with a similar wire across the upper part, on suddenly heating them to whiteness a rapid combustion passed up the first vessel whilst in the other no such combustion took place except immediately above the platinum wire. He also found that the minimun explosive proportion with marsh gas is 5¼ per cent. in an upward direction, and 6¼ per cent. in a downward direction. (2) The products of combustion are too distinctly separated from the inlet air. (3) The lamps are subject to down currents from the top. This latter objection is, however, successfully overcome in the Gray lamp (fig. 192) by inserting two truncated cones united at their small ends within the outlet cylindrical tube.

521. What class of metal should be used in the construction of safety lamps?

A good non-conductor of heat. Brass is generally used, but if replaced by iron the same lamp will give 30 per cent. more light.

522. What is the best form of wick?

Flat, as it produces a superior light without increasing the consumption of oil, and is less liable than a round wick to smoke. This feature has been particularly observed in the Gray lamp.

523. What oils are the safest and best to use in a safety lamp?

Colza, rape, or seal oil, and the report of the Mines Accidents Commission of 1886 recommends the addition of one-half volume of petroleum of a safe flashing point to notably improve the power and uniformity of illumination.

524. What oils are condemned by the Belgian Safety Lamp Commission of 1868, and the English Mines Accidents Commission?

Petroleum, colzalene, benzine spirits, and any other volatile and easily inflammable oils.

525. Are any of the above oils in daily use?

Yes; benzine, colzalene, and petroleum are all in use.

526. Why has the latter class of oil been extensively adopted?

Because of its cleanliness, superior illuminating power, and cheapness.

527. What has been the most important addition during the last few years to safety lamps which receive their air supply from above the flame?

A complete shield to the gauze.

528. Which are the best known shields adaptable to any form of gauze safety lamp?

The Ashworth outer shields (figs. 154, 155), tested by the English Mines Accidents Commission, August 4, 1882. The Marsaut outer shield (fig. 159), tested as above, June 5, 1883. The Smethurst outer shield (fig. 178), tested as above June 22, 1883. The Ashworth inner shield (fig. 156), tested as above, March 13, 1884. The Morgan arrangement (figs. 183 and 184).

529. Where these the first shielded lamps known?

No; the original Clanny (fig. 119) was completely shielded; 1833, the Upton and Roberts (fig. 139) was completely shielded; 1849, the Biram (fig. 199), outlet gauze shielded; 1850, the Eloin (fig. 152), inlet and outlet shielded; 1852, the Jack Davy (fig. 143), partly shielded by cylindrical glass; 1874, the Williamson (fig. 136), outlet shielded; the Gray (fig. 192), whole of the lamp shielded.

530. Can you give a sketch and description of Liveing's indicator for the detection and measurement of inflammable gas in the atmosphere of mines?

Although a mixture of marsh gas and air, in which the marsh gas forms less than between 4 and 5 per cent. of the mixture, is not explosive under ordinary conditions, such a mixture will burn if brought into immediate contact with some sufficiently heated object, especially platinum, and in so doing will add materially to the temperature of the object, and to a greater extent in proportion to the percentage of gas present. To apply this principal to the detection of gas, Mr. Liveing employs two small spirals of platinum wire, so arranged that they can be heated to redness by turning the handle of a small magneto-electrical machine within the instrument. One of these platinum spirals is hermetically sealed in a small brass cover, having a glass end containing pure air, the other spiral is enclosed in a cover, made partly of wire gauze, and to this (which may be called the working spiral) the air of the mine has access. When the air in the mine is free from gas both spirals may be clearly seen to glow with equal brilliancy on turning the handle of the instrument; but if the air contains gas, the working spiral will be seen to glow with greater brilliancy than the covered one. With ¼ per cent. a difference of brilliancy is observed, and with 2 per cent. the working spiral is nearly five times as bright as the covered one. Between the spirals is a small sliding wedge-shaped screen, one side of which is illuminated by the working spiral, and the other by the covered spiral. This is moved by the operator, until both sides appear equally bright, and a scale indicates, at a glance, the percentage of gas present in the air. For the examination of the air in the return airways of a colliery, this instrument at once enables a colliery manager to determine the quantity of gas evolved in the different working districts, and to regulate the proportion of the various currents of air, so as

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to make the best use of the ventilating power at his disposal. If a record of the observed percentages of gas is kept, the quantity of air passing and the barometric pressure being also noted, it will soon become evident within what limits the gas usually varies; and should at any time an abnormal increase be observed, the return can be followed up to its source, and the necessary precautions taken—the effect of the possible presence of coaldust being always borne in mind. The most convenient mode of holding the instrument when in use in situations where no object is at hand is to rest it upon the knee in a stooping position, as in fig. 200, or against the body firmly, as in fig. 201. The instructions issued by Messrs. Latimer Clark, Muirhead and Co., of Regency Street, Westminster, who are manufacturers of this indicator, are very full and clear.

531. Can you name any lamps which have passed the flame when tested in a quiescent atmosphere as a consequence of facts stated in answer to question 520?

Yes. The Bainbridge, Boty, Clanny with chimney and no horizontal gauze, large Davy lamp, Belgian Mueseler, Stephenson, Williamson, Westphalian with unprotected inlet and Rosenkrantz chimney.

532. What important addition has the English Mines Accidents Commission recommended to be made to all shielded lamps?

A "shut-off" arrangement to completely extinguish the wick-flame and ignited gas when necessary. Examples of lamps fitted with this arrangement are the Marsaut, applied to the inlet above the flame; the Evan Thomas, also applied to the inlet above the flame; the Von Buschmann (fig. 202), applied to the inlet below the flame; and the Birckel (fig. 160), applied to both inlet and outlet.

533. What means are used for preventing unauthorised persons opening safety lamps?

By locking. The best known and the most generally used are the set screw; the padlock of Biram, 1849 (fig. 199); the lead rivet used by Mackworth in 1852 (fig. 203); the pneumatic lock of Devismé, 1854, and Purdy, 1879; the magnetic locks of Bidder and Craig, 1869, and Wolf; the cryptograph lock of Baird Bros.; the Protector lock of Mr. Teale; Ryder's sliding bar and lead rivet for locking the shields and oil vessels of bonneted lamps (fig. 204); the Morgan lead rivet arrangement (fig. 205).

534. What systems of locking are arranged to put out the wick flame when the oil vessel is removed from the body of the lamp?

The Protector lock, as applied to gas oil lamps, is probably the best known, and is very efficient. The Douglas and Mason, applied to Davys burning ordinary oil; the Ashworth and the Haworth, both similar to the Protector; the Leech; the Reay; the Mercier (fig. 176).

535. What is the best means of protecting the glass of a safety lamp from fracture by expansion; and, if fractured, to prevent its falling to pieces?

By fitting asbestos, india-rubber or leather rings between the metal and the glass to allow for expansion; and a very light copper or brass ring round the top and bottom of the cylindrical glass to hold it together in the event of fracture. Continental safety lamp makers attach the ring which clips the top of the glass to the base of the gauze, thus ensuring a perfectly safe connection between these important parts of the lamp. A truncated conical glass is stronger and safer than the ordinary cylindrical form.

536. Of what metal should the oil vessel be made?

A metal which is a bad conductor of heat, and on which the oil will not act chemically; as brass is most generally used, it ought to be coated inside with tin to preserve it from verdigris.

537. Can you give a table to illustrate the percentage of gas as shown by the cap on the safety lamp?

Yes, the table, which will be found at the end of this chapter, was given in illustration of a paper read before the North Staffordshire Institute of Mining and Mechanical Engineers, by Mr. A. R. Sawyer, one of her Majesty's inspectors of mines, by whose courtesy I am enabled to insert it for the use of my readers. (Figs 206 to 213.) It has been specially arranged to illustrate how a small percentage of marsh gas may be detected in the air-currents of underground workings. In explanation of the table Mr. Sawyer says, " I have found it convenient and helpful for the purpose of noting the result of examinations of working places and returns, to construct a table showing a gradually increasing cap, as I have been able to perceive it by a prolonged and careful examination of the reduced blue flame of my lamp underground, and to indicate the variation by numbers. I have adopted as the distance from the level of the tube to the top of the wickholder the maximum limit allowed in Belgium—namely, ·985 in. I. (fig. 206) represents absence of any cap. II. (fig. 207), the tip of the cap is too pale to be visible, but the corners are distinct. I have been unable to detect this on the Davy. III. (fig. 208), the tip of the cap, which is very distinct, reaches to about one-third the distance between the wickholder and the level of the tube. As high a cap can be seen on the Davy with care in an undisturbed atmosphere, but it is not half so distinct as in the Mueseler, and the outlines are not so well defined. IV. (fig. 209), the top of the cap reaches to about two-thirds the distance to the level of the tube and is visible at a distance. This can be distinctly seen on a Davy lamp. The approximation of the percentage of gas represented by the different sizes of caps I have derived from the account of experiments appended to this paper. There are returns in this district (North Staffordshire) which I have noted down as I.; the majority, however, show II.; and a few III.; in a working place I consider III. bad, and IV. dangerous, as then an increase of only 2 per cent. of gas will bring the air of the mine up to an explosive point, and causes, ordinarily of small importance, will then play an important part in raising the percentage. In dusty mines where blasting is going on II. is exceedingly dangerous. The oscillation of the flame in the Davy in fast returns makes it impossible to discern less than V. (fig. 210), and then a certain amount of luminosity has to be retained."

538. What is the lowest percentage of gas in which you would deem it safe to carry on blasting operations in the underground workings?

When speaking on this subject, Mr. Sawyer says, "I may say from my own experience, in dusty mines in which the air-current contains a percentage of gas, dangerous enough in the presence of the flame of a shot, but ordinarily invisible in the lamp, that percentage must occasionally so increase as to show II. or even III. in the lamp, and this occasional find ought to be enough, if not to induce the total abandonment of blasting, to restrict it to a minimum, and this only in the morning before the men descend and the pit has had time to cool, and after a most careful examination on the part of trustworthy men has been made. Although it might be said that in such mines one or other of the several perfect and ingenious indicators of small quantities of firedamp should be used, as a matter of fact they are not generally in use, and I am afraid their introduction will be attended with great difficulty, so that one is reduced to making the most of lamps as gas indicators. I am certain that much can be made of them for that purpose. Managers should satisfy themselves that firemen and shot-firers are capable of observing these lamp tests, and are taught them. Persons with defective vision or suffering from colour-blindness should be disqualified from undertaking such important duties the satisfactory performance of which is of so much consequence. Some time ago I used to meet with officials who, I believe honestly, could not even see a "least show" on the flame of their lamps, on which I saw a small but distinct blue cap (III. fig. 208). I still find that the blue flame test (which is of the utmost importance for ascertaining the condition of the air in drifts, where, perhaps, blasting is carried on, still more in dusty mines) is not universally in vogue, and I consider it high time that the matter should be taken up at all collieries." The author holds with Mr. Sawyer that blasting operations should be totally abandoned where the cap on the flame of the safety lamps shows as III. (fig. 208).

539. Has the form of wick and burner anything to do with the illuminating power of the safety lamp?

Yes; the illuminating power of the safety lamp is affected by the form of wick and the material of which the burner is made. Speaking upon this subject, Professor P. P. Bedson, D.Sc., in his paper before the North of England Institute of Mining and Mechanical Engineers (printed in the *Transactions*, Vol. XXXV., Part I.), says "The form of the burner, in the case of the safety lamp, is, of course, the same as that of the wick. For benzine a common round wick suffices. A moderately broad flat wick ·32 in. in width, should be used with rape oil, and for a mixture of rape oil and petroleum a much wider wick is required (·59 to ·67 in.) The effect on the illuminating power of a flame produced by the burner can be observed in any ordinary gas flame. The size of the blue non-luminous zone relative to the luminous portion will be seen to increase with the higher conductivity; hence steatite burners are more economical than those made of metal. Where such materials as rape oil, and mixtures of rape oil and paraffin are used, the heat conducted away by the burner is so small, compared to that used in the distillation of the oil, as to need no consideration; but, in the case of benzine, it would be useful to try what, if any, advantage would result from the use of a wickholder constructed of steatite or other like material."

540. Does the quality of oil, or the mixture of oils, affect the illuminating power of safety lamps?

Yes; the quality and the mixing of oils are very important. Professor Bedson further remarks:—"The illuminating agents which have, up to the present, been used in safety lamps, either in practice or merely experimentally, are:—*(a)* Rape oil; *(b)* a mixture of rape oil and petroleum; *(c)* benzine.

(a.) Inasmuch as rape oil is not volatile, in order that it may be converted into a combustible gas burning with a luminous flame, the oil must be subjected to the process of dry distillation—an operation effected at the expense of the heat of combustion of the oil itself. Not only are volatile bodies produced in the distillation, but a non-volatile residue—carbonaceous matter—is also formed, filling up, in time, the capillaries of the wick, interfering in this way with the flow of the oil, and producing thick crusts on the wick, requiring constant removal, but in spite of which, this formation soon leads to an irregularity and a diminution in the light produced.

(b.) A mixture of rape oil and petroleum possesses the advantage over rape oil itself in its mobility, by virtue of which it flows more easily into the wick. A special form of wick is, however, required for the burning of this mixture, and it may thus be made to burn with a brightly luminous, non-smoky flame, and continue to do so for many hours with satisfactory regularity, the wick requiring but seldom to be freed from the solid matter, which in the use of this mixture makes its appearance more slowly than is the case when rape oil alone is burnt. With a properly-constructed wickholder a mixture containing as much as 50 per cent. of petroleum may be used; the higher the percentage of petroleum the smaller the tendency to the separation of carbon in the wick.

(c.) Owing to its volatility, benzine reaches the wick completely, and is converted into gas, which burns away entirely without any separation of carbon. Benzine possesses, therefore, the great advantage that it burns with a highly luminous flame without the wick being destroyed or undergoing any change."

541. Have you had any experience with the typical Belgian Mueseler safety lamp? If so, do you consider it a good and reliable lamp in a fiery seam?

Yes; I have had experience with the typical Belgian Mueseler lamp, both in North and South Staffordshire, and consider it to be one of the best lamps. It is a good lamp for detecting small percentages of gas, to which it is very sensitive. Mr. Sawyer, inspector of mines for North Staffordshire, introduced the first Mueseler lamp into that district, and says they are now in use in every colliery more or less. He also states that "all the officials and men who have handled them daily for a sufficient length of time to have become accustomed to their use, speak in favour of them, not being, so far as I know, inconvenienced by their liability to extinction when held to one side too long. I have found that the lamps can be tilted long enough to examine the roof, without going out, and the limit of time to be allowed becomes instinctive. The extinction of the lamp in bad hands is a guarantee against abuse, and is highly to be commended. Though quite convinced of the superiority of the Mueseler to the Davy lamp as a gas detector, as well as a working lamp, I have thought it advisable to put this beyond any doubt, and for that purpose I have placed the results of about fifty experiments in a tabular form before the members of this institute (North Staffordshire Mining and Mechanical Engineers), of whom some were present when these experiments were made. The experiments were conducted with the greatest care and as much accuracy as was possible under the circumstances, and the result of each experiment made has been noted down. I did not specially choose the places, but conducted the experiments wherever gas was reported to me. Having been conducted underground, and in conditions which are met with daily, these experiments, though, perhaps, rough and ready, are to my mind of as much value as many such conducted in a laboratory, under conditions which are, perhaps, seldom experienced. These experiments, though made principally with a view to test the lamps as gas detectors, show very forcibly the great superiority of the Mueseler over the Davy lamp in the hands of colliers at fiery collieries. The Mueseler was always extinguished in explosive mixtures after a few seconds, except where purposely lowered in time for the flame to remain in. The gas in the Davy, with one or two exceptions, continued burning, and would have done so until the lamp became red hot and ignited the gas outside. Though the firedamp showed different characteristics as regards smell and feel, I believe it in the main to have been a mixture of marsh gas (CH_4), hydrogen, and carbonic anhydride (CO_2), with, perhaps, in some cases, some olefiant gas (C_2H_4), and a little sulphuretted hydrogen (SH_2)."

542. Can you give the dimensions of the important parts of the typical Mueseler lamp.

Yes; the accompanying table gives the dimensions and descriptions of the most important parts of the typical Mueseler lamp, and fig. 214 is a section of the lamp, for both of which I am indebted to Mr. Sawyer's paper. The typical Mueseler lamp has been improved upon since it was first introduced in England. For example, the bonneted Mueseler, as recommended by the Royal Commission on Accidents in Mines, is an improvement. Mr. James Ashworth has also made several improvements in this lamp, the main feature being the double bonnet or shield; the intake and outlet air-holes of the inner and outer bonnet not being opposite each other, prevent the air reaching the flame, except at a very low velocity. This lamp is illustrated in fig. 215, and it will be seen that the air supply holes are drilled perpendicularly, so that the air has to travel upwards and pass through a vertical and horizontal gauze before it feeds the flame.

543. Describe any means of shot-lighting with shielded safety lamps?

(I.) A hole bored through the cylindrical glass shield of a Davy lamp. (II.) Ashworth's shot-firing tube, viz., a tube of small diameter, through which the firing-wire is passed to the flame. (III.) Heath and Frost's (fig. 216).—In out-

TABLE SHOWING THE DIMENSIONS (IN INCHES) AND DESCRIPTION OF THE MOST IMPORTANT PARTS IN THE LAMPS AUTHORISED BY THE BELGIAN ROYAL DECREE OF JUNE 17TH, 1876.

LAMPS ALLOWED TO BE USED.	GLASS CYLINDER with metallic ring at both ends.			INTERNAL CHIMNEY. A conical sheet iron or copper tube with a funnel-shaped enlargement at its base.							Height of outer gauze.	Minimum diameter of gauze wire.	Minimum openings in a square inch.	Persons by whom or purpose for which the use of the lamp is authorised.
	External diameter.	Thickness of Glass.	Maximum height of glass including thickness of bottom ring.	Maximum internal dia.			Length of Chimney.		Height of enlargement.	Distance from bottom of chimney to top of wickholder.				
				At Top.	At Base.	At place of enlargement.	Above horizontal gauze.	Below horizontal gauze including enlargement.						
Typical Mueseler,* Plate VII.	2·364	·216	2·442	·394	1·182	·985	3·546	1·063	·236	·866	4·294	·013	928	Workmen.
Practical limits allowed.†	From 2·324 to 2·403	From ·197 to ·295	2·442	·394	1·024	No enlargement.	3·467 3·624	·985 1·142	No enlargement.	·788 ·945	4·137 4·452	·010	928	Workmen.
Mueseler large type.	From 2·364 to 2·758	From ·216 to 3·152	3·937	·591	1·379	No enlargement.	‡5·516	§1·497	No enlargement.	...	...	·013	928	Stationary lamps in or near shafts.
Mueseler-Godin (Deputy's lamp).‖	Limits allowed as in typical lamp.											75	...	...

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* Principally used in Liége coalfield.

† Variations within these prescribed limits and absence of funnel-shaped enlargement at base of chimney occur principally in the Hainaut coalfield.

‡ If the mean of the internal diameter of the chimney at top and base is ·788, its length above the horizontal gauze must be at least 3·546. For every additional ·039, ·393 must be added to the height above the gauze.

§ The length of chimney below gauze must be at least equal to half the distance from gauze to wickholder.

‖ It possesses an internal glass cylinder supported on an ordinary stand, through which the air enters to the flame.

ward appearance this is a Mueseler lamp, but passing through the oil vessel and up the chimney and out at the top of the cylindrical gauze is a tube just large enough at the bottom end to admit a full-sized fuse. When in use the semicircular wire (*w*, fig. 216) is moved into the wick-flame, the fuse is then pushed up the tube until it comes in contact with the wire (*w*), which, at the time, passes right across the tube. As soon as the wire is sufficiently heated it is withdrawn, and in passing over the end of the fuse lights it. The smoke and sparks pass upward until they enter the part above the gauze, which is called the condenser (*c*, fig. 216). The inventors claim for this arrangement that a shot of strong explosive may be safely fired under conditions that would be absolutely dangerous if the ordinary means of ignition were applied.

544. Give a short description of an electric safety lamp.

Perhaps the best electric safety lamp yet produced is that invented by Mr. Joseph Wilson Swan, which, although not yet perfect so far as its adaptation to practical mining is concerned, has been so improved upon by Mr. Swan since its original inception as to give promise of ultimate success. The battery is constructed as follows:—The core is a lead wire surrounded by peroxide of lead. This is covered by a wrapping of cloth, outside which, and filling the space between the oxide cylinder and the interior lead lining of the containing tube, is a packing of lead filament. The lead filament is in contact with the lead lining, and that with a strip of lead which forms one of the outward conductors, the lead wire, forming the core of the oxide cylinder, being the other conductor. The electrolyte is, as usual, dilute sulphuric acid; adhesion to the lead filament prevents the liquid from spilling if the battery is inclined to one side. The terminals are attached to two elastic strips of brass, and these hold the little lamp between them with a slight end pressure, and in such a simple manner that it is removable in a moment. The lamp is protected against external injury by a very thick glass bull's-eye, and light is economised by a silvered reflector behind the lamp. Two sockets within the case provide the means of connecting the battery terminals with the charging circuit. There is also a switch of simple construction which enables the current to be turned off or on the lamp, the object of this being to avoid waste of current by keeping the circuit uncompleted until light is required. Contact is made and broken within a small cavity in the switch plate containing a single drop of oil. Even without this precaution there is not the slightest danger of ignition of explosive gas by a spark produced at the switch on opening the circuit. The spark, on breaking the circuit, is exceedingly minute—so minute, indeed, as to be quite invisible to the naked eye; even in absolute darkness the aid of a lens is required to see it. Since the above description was written Mr. Swan has made further improvements. The battery which supplies electricity has been simplified by using only two cells in some cases and four cells in other cases, instead of the seven before required. The lamp is now fitted so as to better resist a shock or blow, and the cells made liquid-tight, so that the lamp may be inclined or even inverted, without leakage. The lamp has also been reduced in size and weight, and altogether made more like an ordinary safety lamp in general form. There are also modifications made with a view to facilitate examination of the sides and roof of the mine, or with a view to hewers' work. With the reduced weight and size of battery, the lamp still gives over a candle during the full time of the shift. Another point in which the lamp is improved is that the terminals are brought down to the bottom of the battery-case, and can be got at for the purpose of making connection with the charging circuit without removing the cover. The power of the light is simply dependent on the weight of the battery; double weight giving double light, and so on; so that where an extra amount of light is required, it can easily be had without necessitating a change of design in the lamp, or in any way lessening safety. The two great sources of danger in coalmines—firedamp and falls of the roof and sides—are both guarded against by the electric lamp; the danger of explosion, by the light being entirely out of contact with the atmosphere of the mine; and danger from falls of the roof and sides, by the better light procurable by means of electricity. The batteries are charged by setting them down on a charging bench, to which the current is brought from a small dynamo, and simply leaving them there while the men are off work. Perhaps once a week a few drops of dilute acid will have to be added to compensate for loss by effervescence during charging. Five-horse power would keep 1,000 lamps going—500 on the charging circuit and 500 in use in the mine. The cost of lamp renewals would be the heaviest charge, amounting, Mr. Swan estimates, to 2d. per lamp per week, and where the number of lamps were considerable 1d. or 1½d. for keeping the lamps charged and in order. Another 1d., making 4½d. per week, would cover the charge for interest on the capital outlay for first cost of lamps and other plant. Mr. Swan has also added a firedamp indicator to his lamp.

545. Name other electric lamps that are in use for lighting underground workings.

The Pitkin lamp is supplied with cells within which the electricity is stored; the Settle lamp is supplied by wire direct from the dynamo. In the Schanschieff and the New Portable each lamp carries its own battery. A great feature in the Schanschieff lamp is its perfect safety, and the fact that no expensive installation is necessary, as is the case where lamps are worked from secondary batteries. The present retail price is about 21s. The exciting liquid is a solution of basic sulphate of mercury, in the acid sulphate, one part of the salt being entirely dissolved in three parts of water, under Schanschieff's patent process. E.M.F. per cell is 1·5 volts; internal resistance 0·1 with zincs 2 in. by ¾ in., giving eight to nine ampère hours. The weight of the lamp complete and charged is about 4¼ lb. The cells are liquid tight, being hermetically sealed. The battery is put in action by reversing it; when in the opposite position the elements and liquid are separated, so that, when thus, the lamp can be suspended for months ready for use. Contact is effected inside the battery by the liquid, on the battery being turned over; therefore sparking is impossible. The cost of the solution, if manufactured by the colliery owner, may be taken at 6d. per gallon. The New Portable electric lamp has two cells, and gives light for eighteen hours, equivalent to one candle, and weighing 4½ lb.; average E.M.F. (in closed circuit for twelve hours), 3·75 volts; current through lamp, ·323 ampère; power expended in external circuit, 1·211 watts; capacity of negative element, 7 ampère hours; the electrolyte used is dilute sulphuric acid; specific gravity of the electrolyte, 1·170; weight of elements complete, 1 lb. 3 oz.; weight of negative element (lithanode), 6 oz.; weight of positive element (spongy lead), 2½ oz.; total height, 8 in.; total diameter, 4 in.

546. Give a description of any system of electric lighting in operation.

The growing importance of electric lighting has drawn such general attention to it that every colliery manager should keep himself informed of the latest developments of electric lighting and of electricity generally, especially as applied to mining. The system adopted at the Cannock Chase Collieries is simple and economical and has been designed and laid down under the superintendence of Mr. Sopwith, the mining engineer at the collieries. The motive power is supplied by a dynamo manufactured by Messrs. Parker and Elwell, electrical engineers, Wolverhampton, guaranteed to work up to 160 lamps of 20-candle power each. It is a very excellent machine, and has worked uniformly well. It is driven by a belt direct from the fan engine which runs on the disc forming the crank, not necessitating, therefore, any new gearing; the speed of the dynamo was 950 revolutions per minute, and this kept 150 lights going constantly, 80 above and 70 below ground. It may be here remarked that a fan engine supplies the best possible motive power, because necessarily it works at one regular speed and is always running, unless the men are withdrawn from the mine, in which case neither ventilation nor light are required; further, it will be seen that the cost of running a dynamo is nominal, a careful calculation showing that only 3-horse power was required to work the one in question, and that it made no observable difference either in the speed of the fan or the quantity of fuel used. The next item is the cable, and ordinarily a copper cable is used, its resistance to the electric current being only one-sixth as compared with iron. At the Cannock Chase Collieries, however, Mr. Sopwith has most successfully made use of the old discarded winding rope, and has thus utilised what could only have been sold as scrap rope in place of a copper cable, which forms one of the most expensive items in an electric lighting installation. The rope has been carefully insulated by wrapping with ordinary brattice canvas and string. The whole of the work of fixing, &c., was done by the colliery workmen and entailed no outside expense. The cable is laid so as to supply the surface, loading places, offices, shopping, &c., and the insets or pit-eyes, stables, offices and roadways within 100 yards of the pit bottom in all directions. The lamp used is an ordinary incandescent lamp, consisting of a carbon filament enclosed in a glass globe, in vacuum, and cost 4s. each. The light on the day of inspection was both brilliant and steady, the latter not being always the case where a dynamo is used. The regulation of the light was under perfect control by means of switches, so that each section could be instantaneously lighted or darkened at will. As to the question of safety, in the event of one of the lamps being broken, the vacuum which is essential to the continuance of the light is destroyed, so that there could be no contact between gas and light. Mr. Sopwith appears to have demonstrated the practicability of the successful and economical lighting of mines by electricity. His system is especially good in two respects: First, it utilises practically without additional cost an existing and uniform motive power, viz., the fan engine; and second, it utilises an almost valueless scrap rope in place of an expensive copper cable. It also supplies a clean, brilliant, safe and cheap light. I noticed on leaving the office that Mr. Sopwith was extending his system to the neighbouring church, school and houses by the aid of a disused flat wire rope and the gas main in lieu of a return cable. Messrs. John Davis and Son, of Derby, manufacture a very good dynamo for electric lighting (fig. 217), which possesses one special feature in that lights can be turned on and off without any attention whatever to the brushes, which is the case in no other dynamo.

547. The Mines Regulation Act of 1887 directs that the examination of colliery workings shall be made within a specified time of the men getting into work. What check can be placed on the official whose duty it is to do this?

Either by chalking the time at each working or by the use of some simple instrument. Such an instrument is the Hahn time detector (fig. 218), which has been in daily use underground in Continental coalmines for several years. This instrument is applicable in every instance where it is important to ascertain with absolute reliability that certain duties have been performed in the specified order, and at the exact time which is required, and may be described briefly as follows:—The tell-tale is enclosed in a metal box and consists of a fifty-hour clock moving a paper dial, on which are radial lines corresponding with the time. The dial is divided into twelve or twenty hours by dark lines, and the intervals are sub-divided into ten and five minutes by lighter lines and short strokes respectively. Projecting over the face of this paper dial is a stationary hand, and below this and the dial, in a slot of metal, are small dies, which, by the movement of a key, are jerked upward, thus causing an impression on the paper. At each station is suspended, by a brass safety chain, a key which, when inserted into the apparatus and turned once round, will jerk upwards the die indicating the particular station. All the keys are different, so as to compel the functionary to visit each station, in order to obtain the impression of the different dies on the dial.

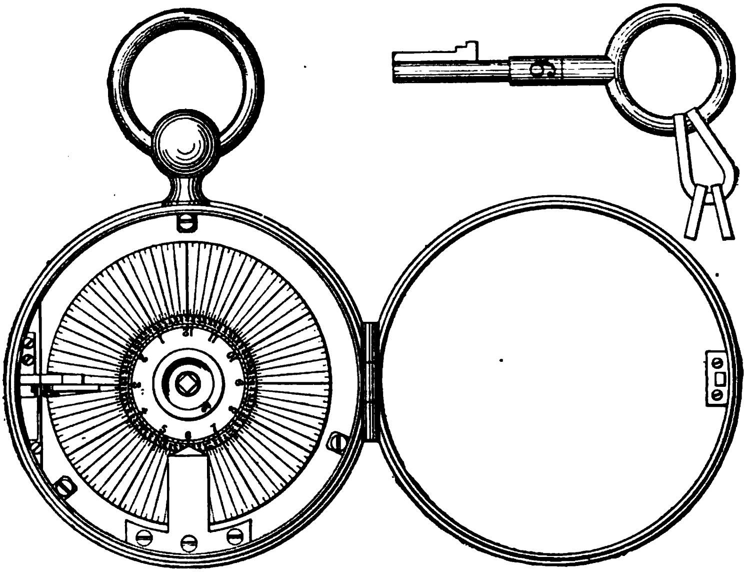
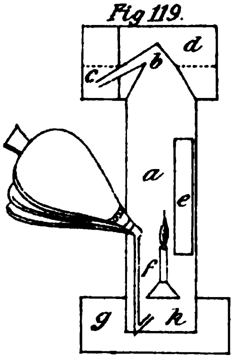


Fig. 218.

* * *

ILLUSTRATIONS TO CHAPTER IX.

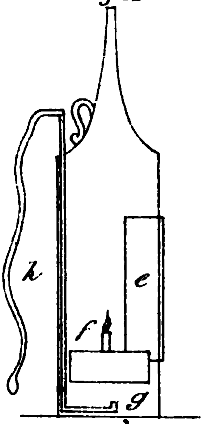
Fig 119.



G & C contain water e, glass.

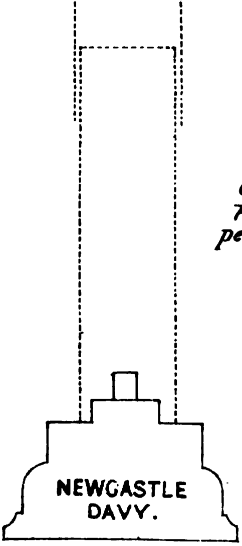
Dr. CLANNY'S LAMP.

Fig 120.



Dr. CLANNY'S LAMP.

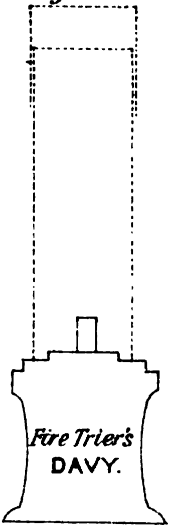
Fig. 121.



NEWCASTLE DAVY.

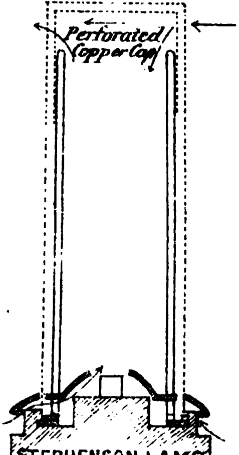
Gauzes 742 holes per sq. inch.

Fig. 122.



Fire Trier's DAVY.

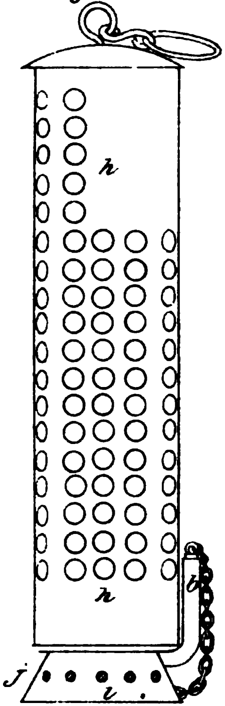
Fig. 123.



STEPHENSON LAMP

Shewing double air-current in the lamp like that within a Clanny.

Fig. 124



ELEVATION

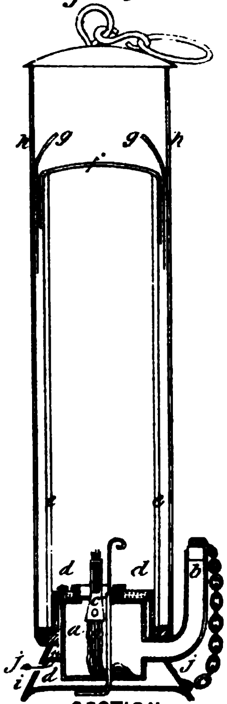
STEPHENSON LAMP.

REFERENCES.

a……*Oil vessel.*
b……*Tube for supplying oil.*
c……*Wick tube.*
d… *Plates perforated with very small holes.*
e……*Glass.*
f……*Copper cap do. do. do.*
g……*Springs to keep glass steady.*
h……*Thin Sheet-iron case with holes $\frac{9}{32}$ diamr. punched, except semi-circumference at top, as shewn.*
i……*Exterior of lamp.*
j……*Holes for admission of air.*

Quarter size.

Fig. 125



SECTION

Fig. 126.

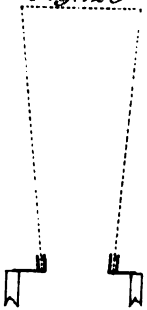


Fig. 129

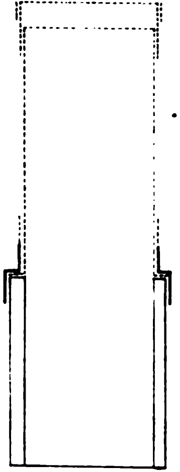


Fig. 130

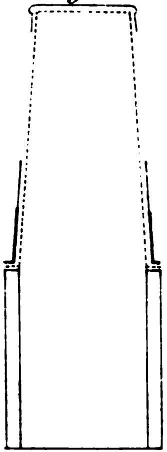
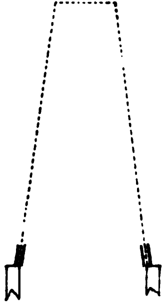
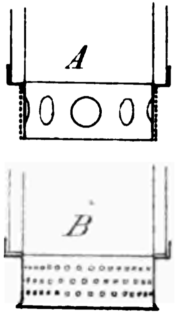


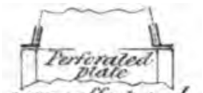
Fig. 127.





A is a safer shape than B
See Prussian report

Fig. 128.



same effect and as dangerous as Fig 7.

Fig. 131

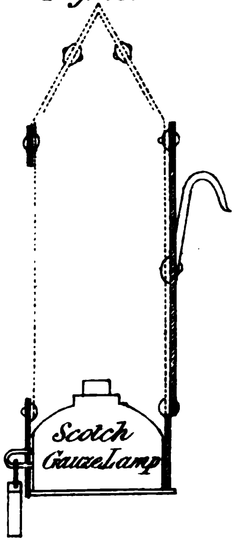


Fig. 132

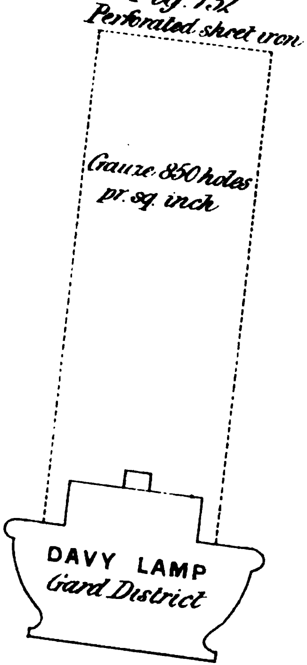
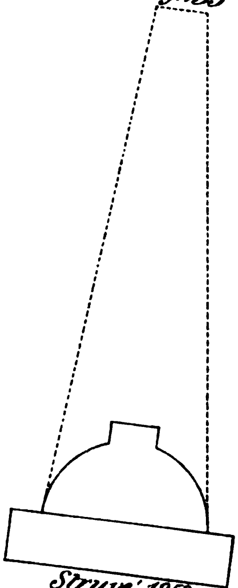
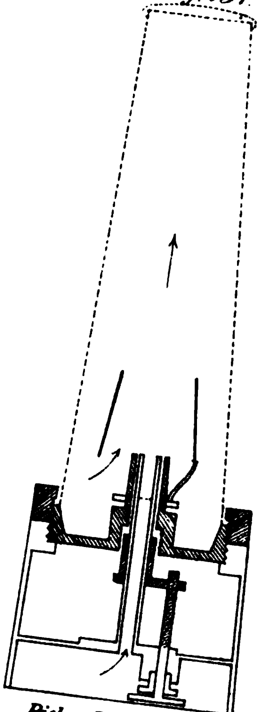


Fig. 133



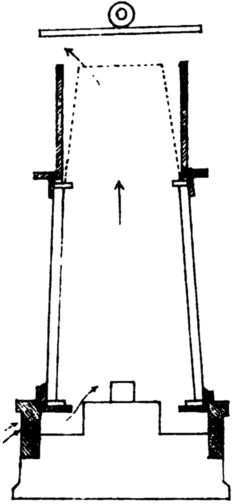
Struve' 1852.

Fig. 134



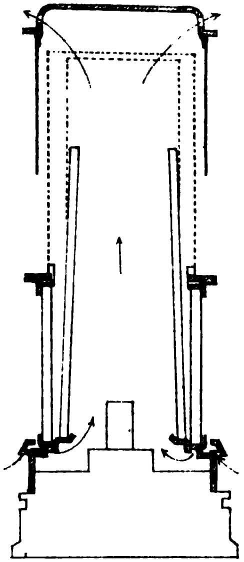
Pieler Spirit Lamp
3 lbs. 6 oz.

Fig. 135.



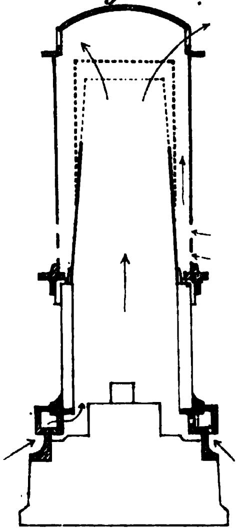
BAINBRIDGE.

Fig. 136.



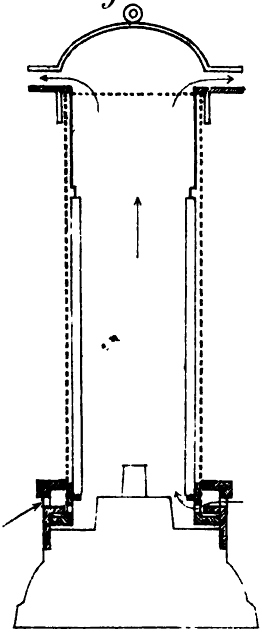
WILLIAMSON. 8.

Fig. 137



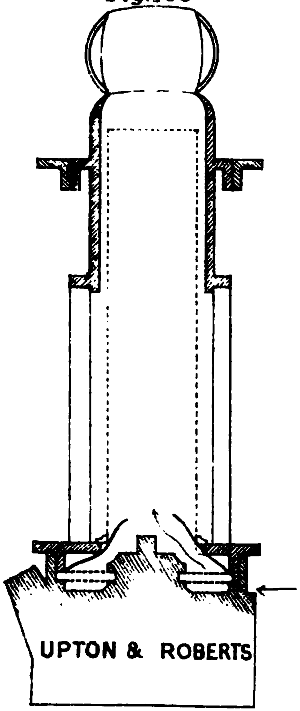
W. PURDY.

Fig. 138.



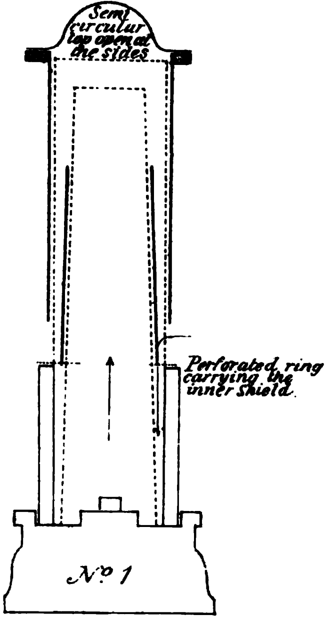
HANN.

Fig. 139



UPTON & ROBERTS

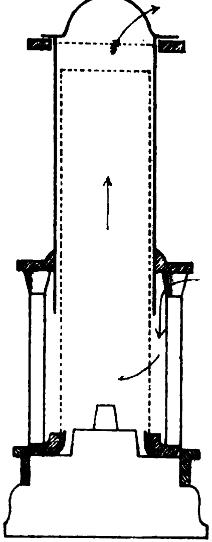
Fig. 140



Semi circular top open at the sides
Perforated ring carrying the inner Shield.
№ 1

ROUTLEDGE & JOHNSON'S.
Double Combination Miner's safety lamp.

Fig. 141



KNOWLES DAVY.
With Glass Shield.

Fig. 142

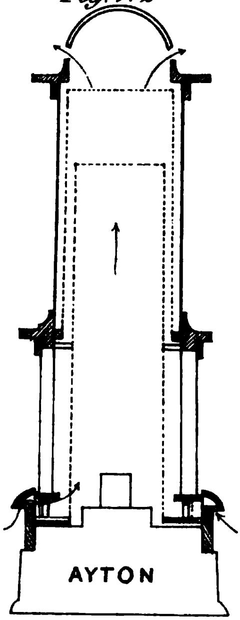


Fig. 143

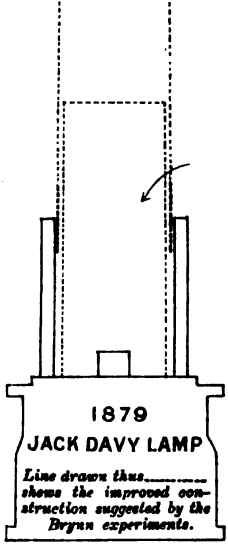

1879
JACK DAVY LAMP
Line drawn thus .... shows the improved construction suggested by the Brynn experiments.

Fig. 144

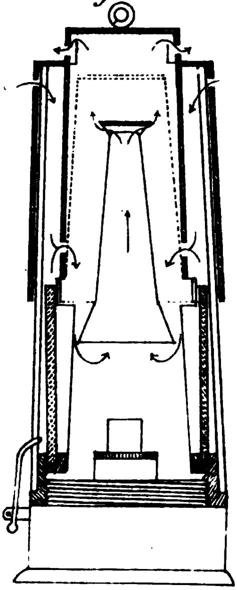


Fig 145

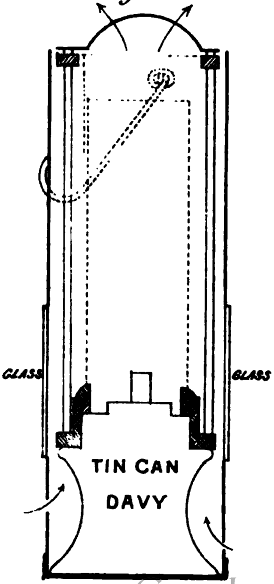
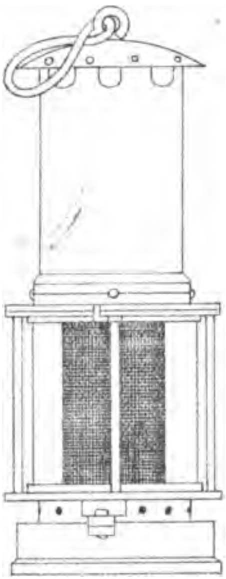
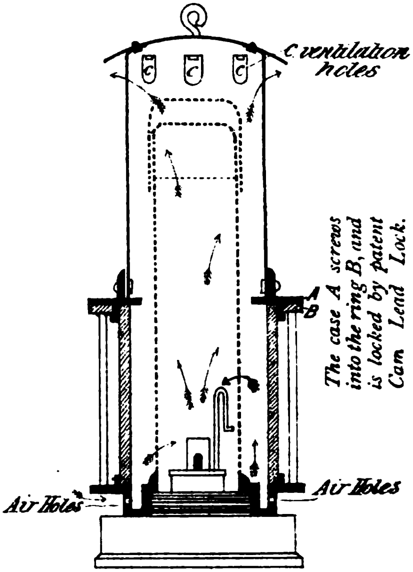


Fig 146.



LAIDLER'S PATENT
No. 9 Bonnetted Davy Lamp, with patent cam lock and lead rivet.

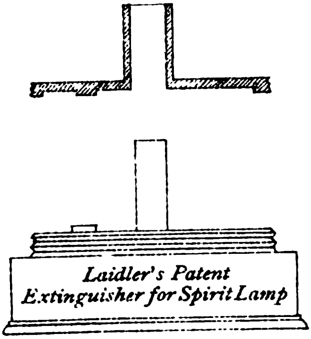
Fig. 147.



The case A screws into the ring B, and is locked by patent Cam Lead Lock.

Section of No. 9 Bonnetted Davy Lamp, Laidler's Patent.

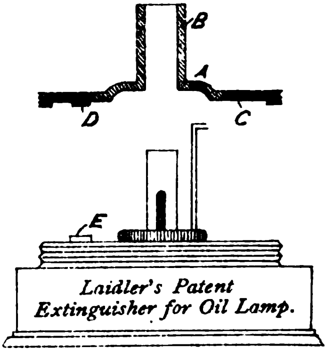
Fig. 148.



Laidler's Patent Extinguisher for Spirit Lamp

The action is the same as in the Oil Lamp Extinguisher, except that the revolving top is not required, there being no pricker used in a Spirit Lamp.

Fig. 149.



Laidler's Patent Extinguisher for Oil Lamp.

The part B revolves in plate C. A is a slot cut into extinguisher to allow pricker to pass. Stop D is caught by stop E, and the extinguisher is thus screwed up with the bottom. The pricker being out of centre the top part of the extinguisher is made to revolve.

Fig. 150.

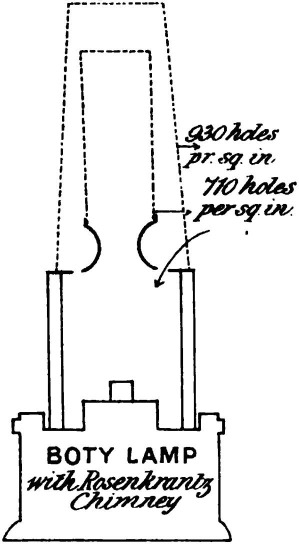
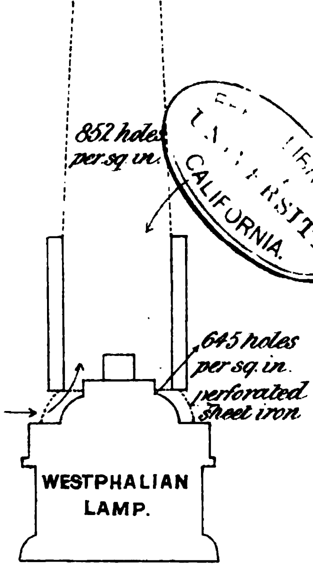
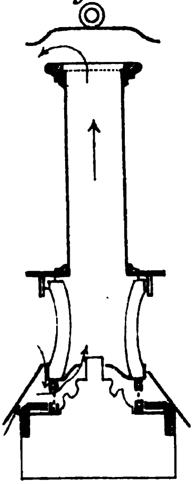


Fig. 151



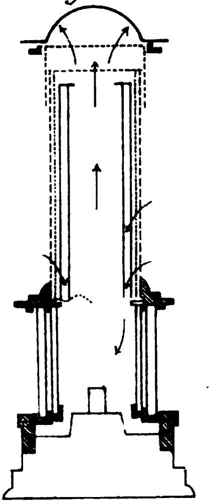
UNIVERSITY CALIFORNIA

Fig. 152.



ELOIN.

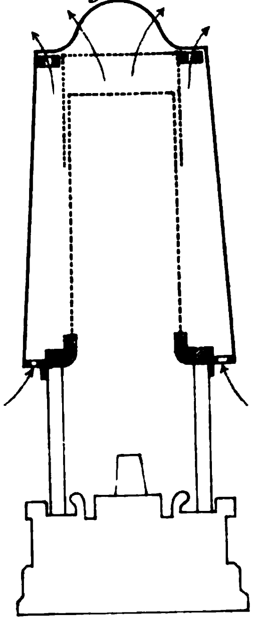
Fig. 153.



PELTON.

The inner cylinder is corrugated as shewn by the dotted line. The cylindrical shield is perforated to correspond with the corrugations.

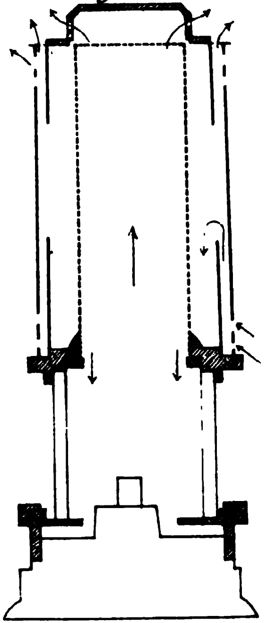
Fig. 154.



ASHWORTH SHIELDED CLANNY

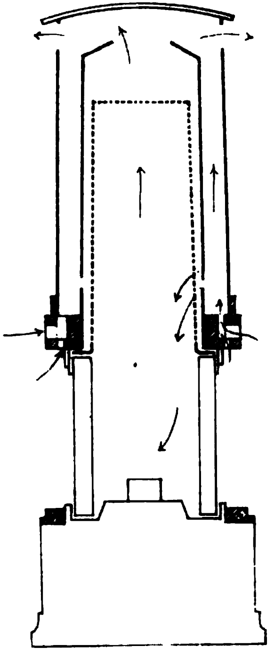
No 17. M.A Commission.

Fig. 155.



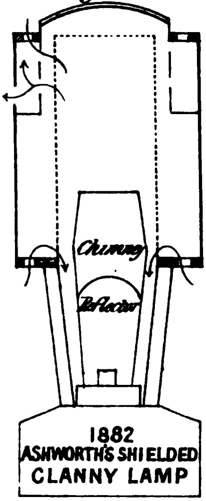
ASHWORTH CLANNY (19)

Fig. 156.



ASHWORTH (4)

Fig. 157



These two lamps were tested on the same day, and both exploded in 35 seconds in a velocity of 35 feet per second, the Marsaut glass being cracked by the heat.

Fig. 158.

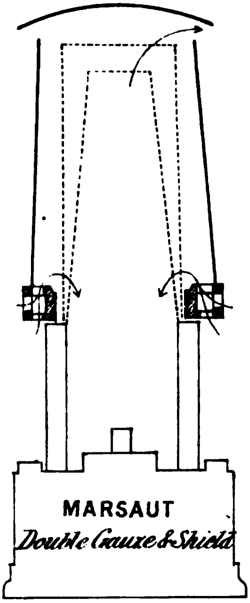


Fig. 159

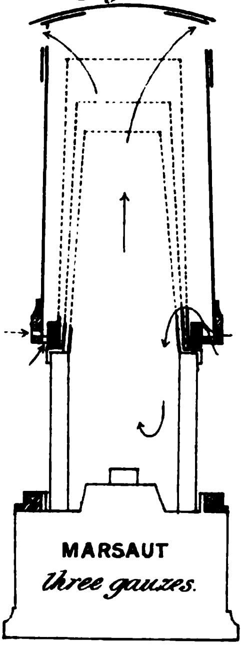


Fig. 160.

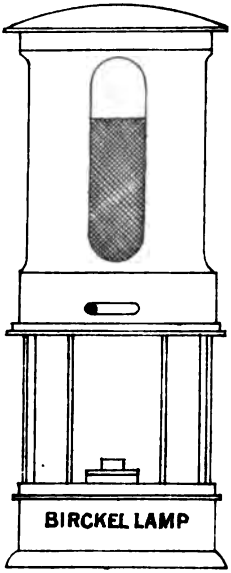
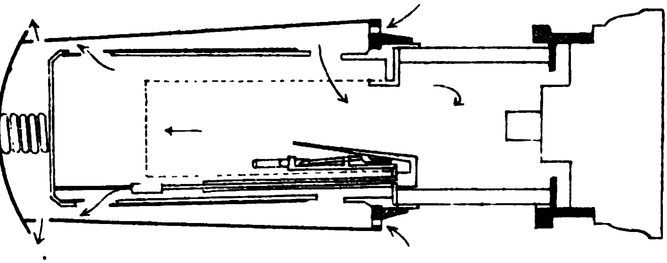
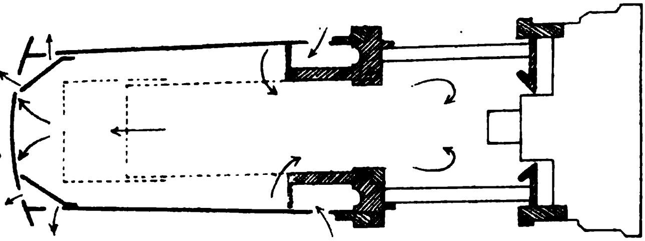


Fig 161



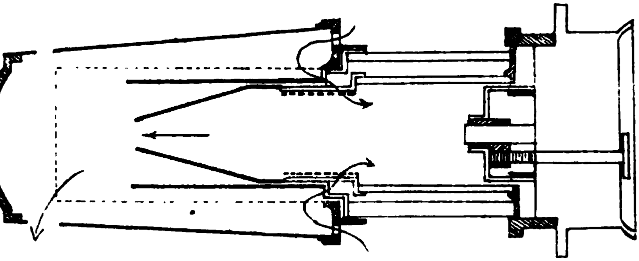
EVAN EVANS
Automatic 'Shut off'.

Fig. 162.



EVAN THOMAS

Fig 163.



THOMSON (2)

Fig. 164.

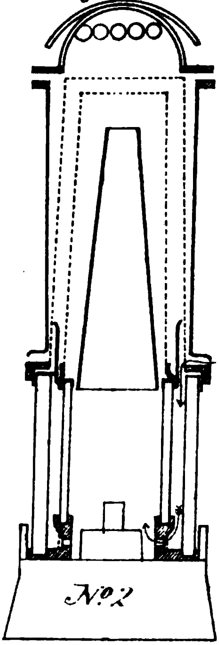
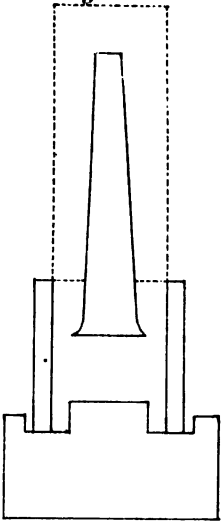
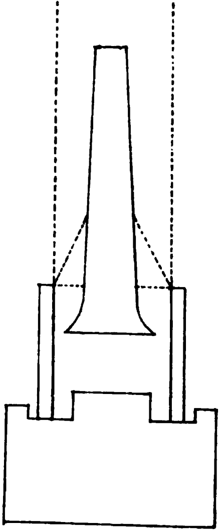


Fig 165.



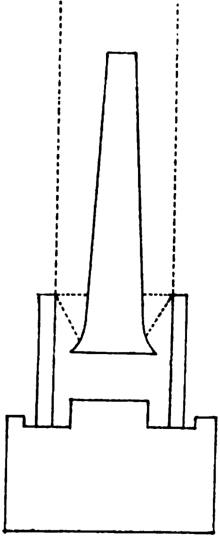
BELGIAN MUESELER

Fig 166



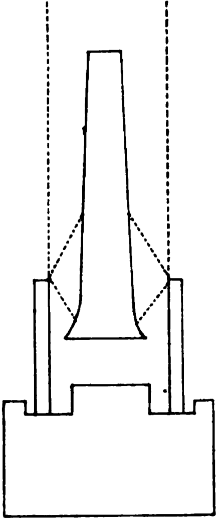
MUESELER-JOASSIN. Nº 1.

Fig 167



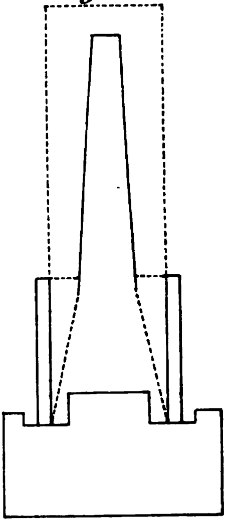
MUESELER-DEMANET

Fig. 168



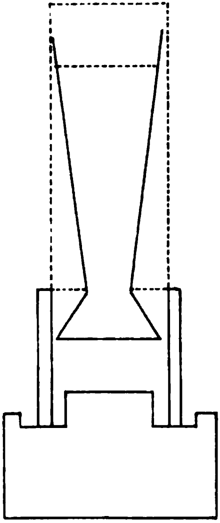
MUESELER-JOASSIN. Nº 2

Fig. 169.



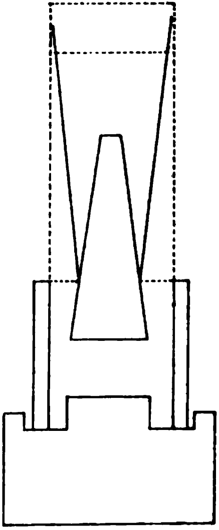
MUESELER-GODIN. G.

Fig. 170.



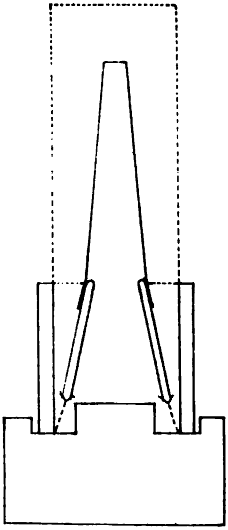
MUESELER-ARNOULD. Nº 1.

Fig. 171.



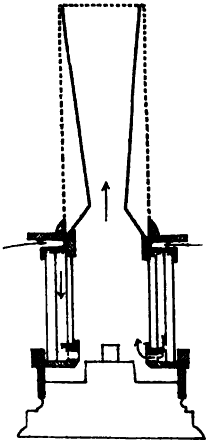
MUESELER-ARNOULD Nº 2

Fig. 172



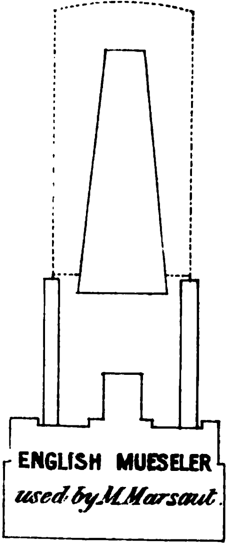
MUESELER ARNOULD GODIN.

Fig. 173



MORISON (4)

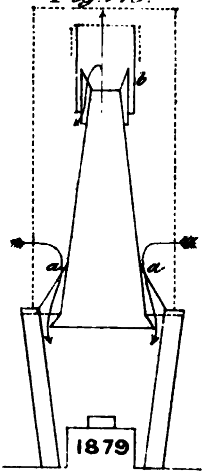
Fig. 174



ENGLISH MUESELER

used by M. Marsaut.

Fig. 175.



LARGE MUESELER LAMP

with chimneypot,

horizontal gauze shield

and conical glass

Ashworth No. 3, M.A.C.

Fig 176

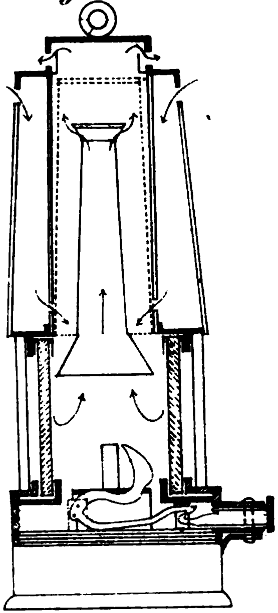
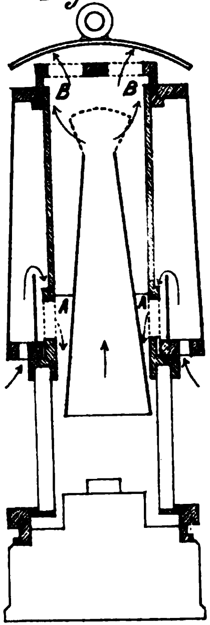
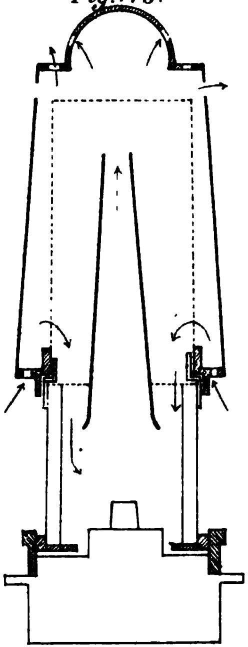


Fig. 177.



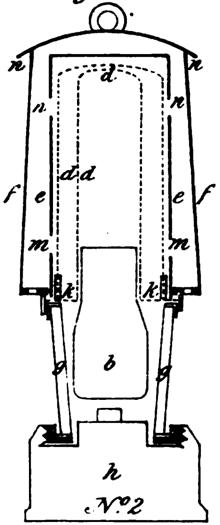
Mc KINLESS
Gauzeless safety lamp
Holes at A $\frac{1}{20}$ inch diam. x $\frac{1}{9}$ inch long.
Holes at B of greater length than diam^{r}.

Fig. 178.



BONNETTED MUESELER
45

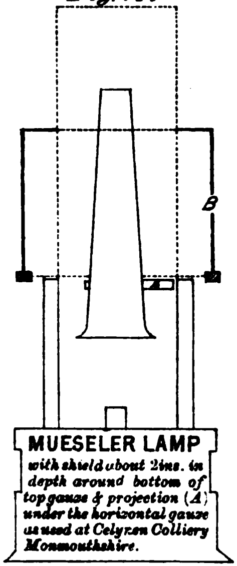
Fig. 179



ASHWORTH–WOOLRYCH

with Ashworth's shields & reflector. This lamp has been tested in velocities up to 52 feet per second without causing any explosion or breakage of the glass.

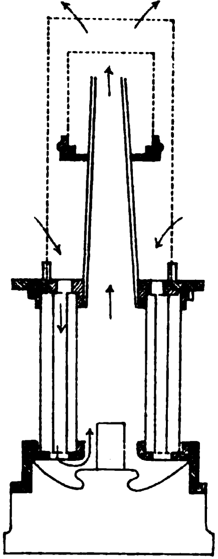
Fig. 180



MUESELER LAMP

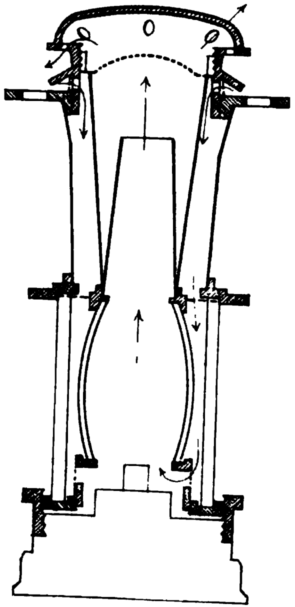
with shield about 2ins. in depth around bottom of top gauze & projection (A) under the horizontal gauze as used at Celynen Colliery Monmouthshire.

Fig. 181



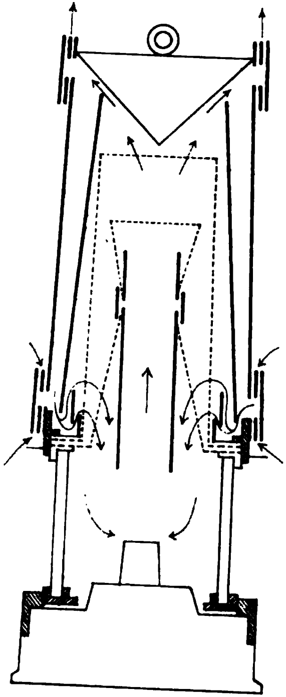
BRYHAM'S MUESELER

Fig. 182



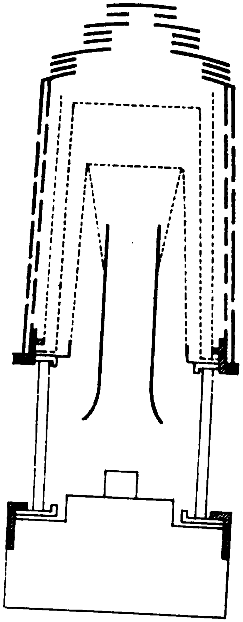
EVAN THOMAS LAMP.

Fig. 183



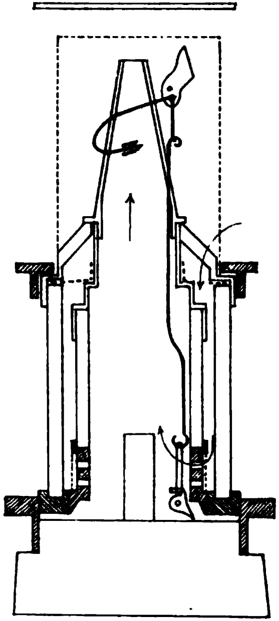
MORGAN
JAN. 1885.

Fig. 184.



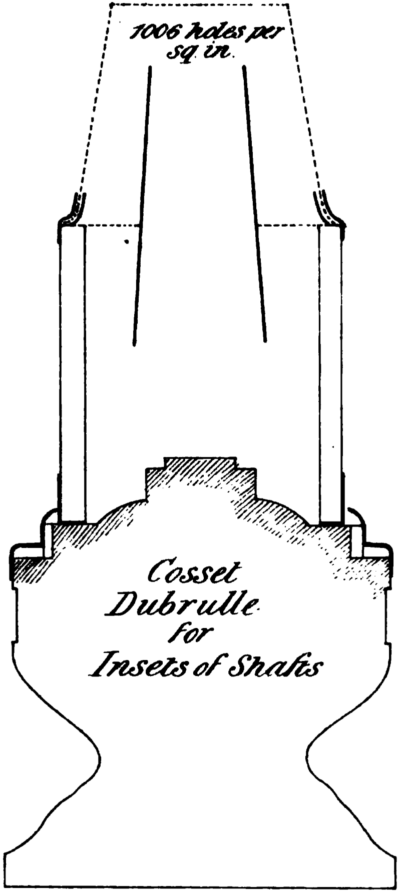
MORGAN

Fig. 185.



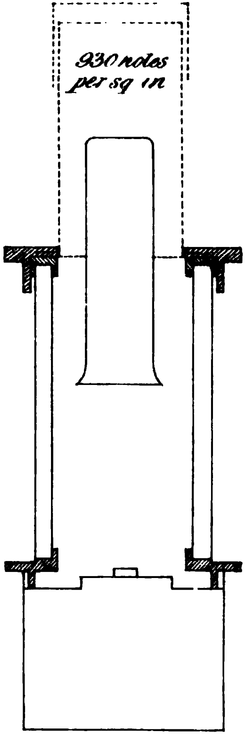
MARSHALL.
1885.

Fig. 187.



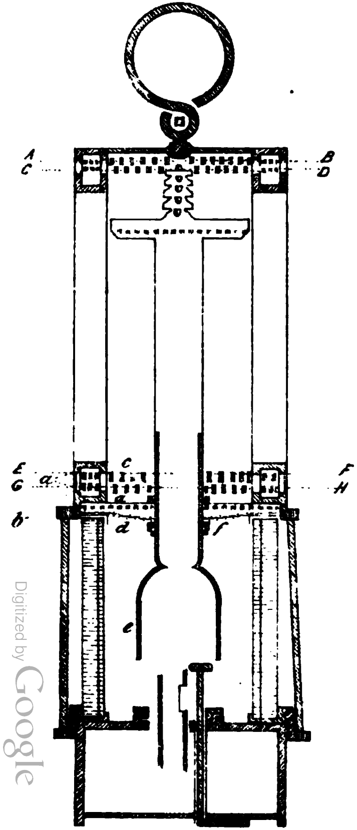
Cosset Dubrulle for Insets of Shafts

Fig. 186.

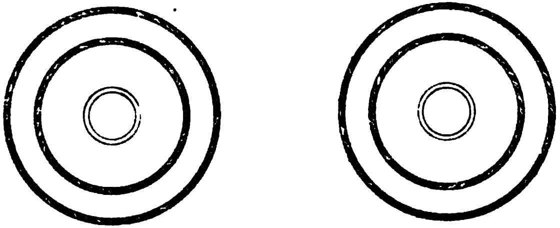


COMBES LAMP

Fig. 188



CLIFFORD LAMP



CLIFFORD LAMP, HORIZONTAL RINGS OR SKINS.

The air enters at *a*, the annular chamber, *b*, thence through the inner skin, *c*, down through the gauze, *d*, and flame chamber to foot of glass chimney, *e*, and wick flame. This chimney is held in position by a gauze lock-nut, *f*, the products of combustion pass up the metal chimney to the outlet.

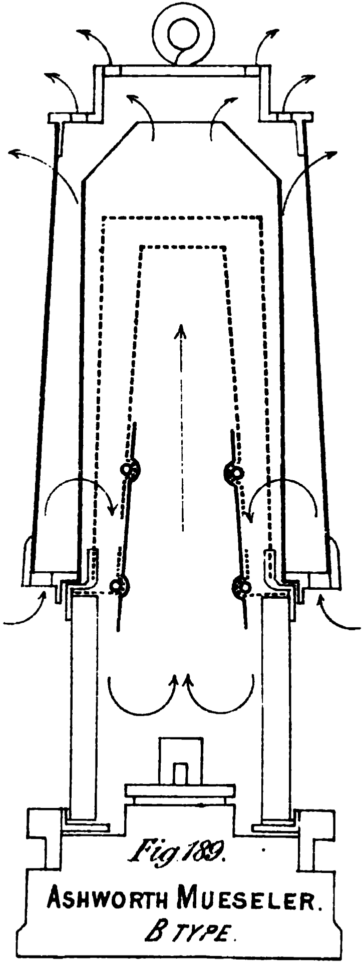
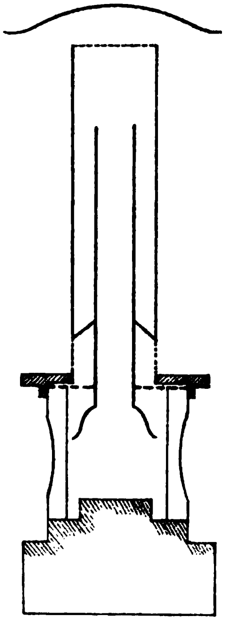


Fig. 189.

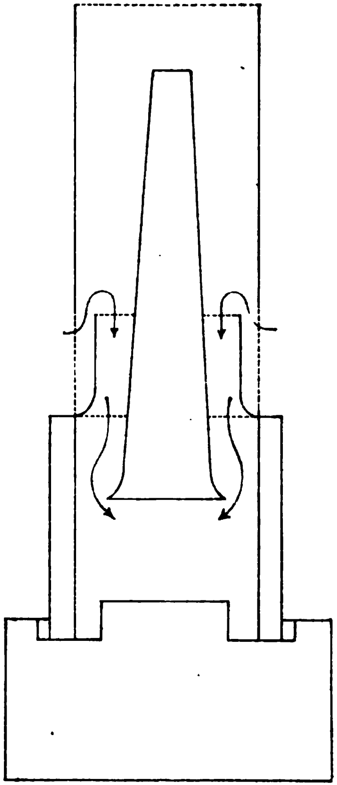
ASHWORTH MUESELER.
B TYPE.

Fig. 190.



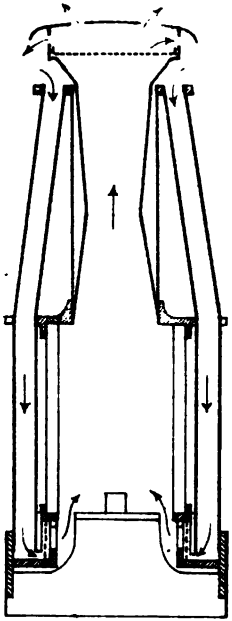
ELOIN MUESELER
1850

Fig. 191.



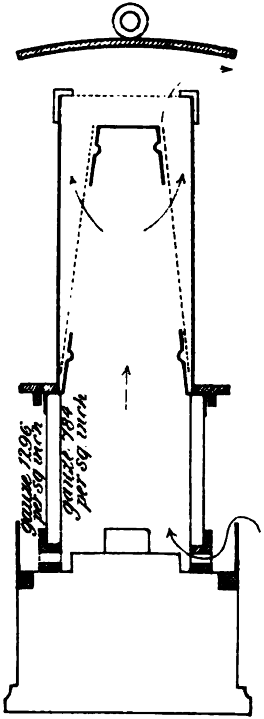
MUESELER GODIN.H.

Fig. 192



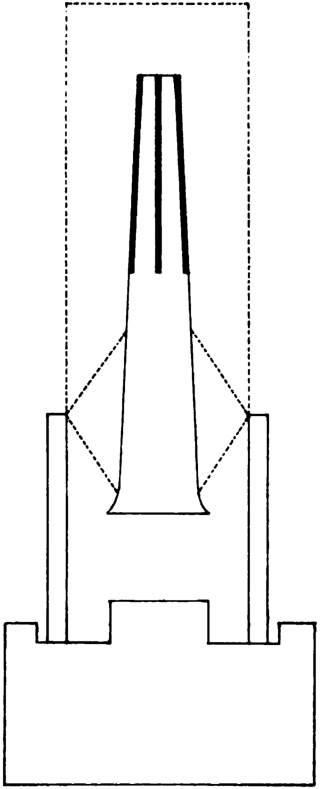
GRAY

Fig. 193.



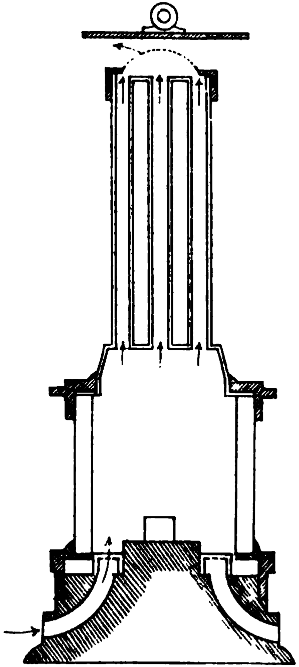
FUMAT (2)

Fig. 194.



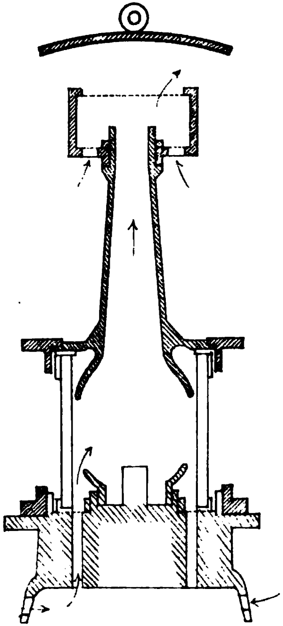
TUBULAR CHIMNEY

Fig. 195.



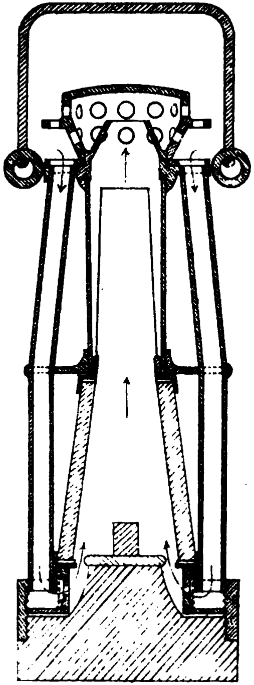
HOWAT. (3)

Fig. 196



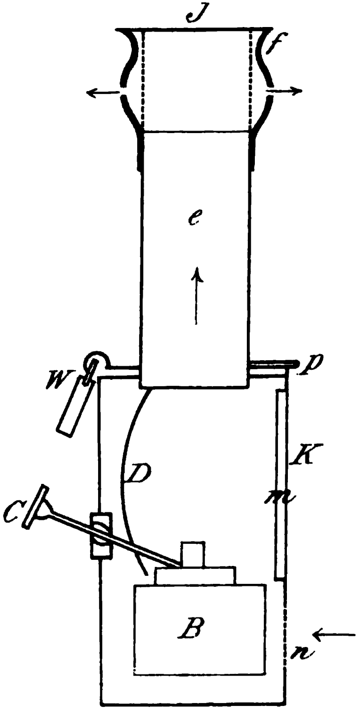
HOWAT. (5)

Fig. 198



ASHWORTHS PATENT
HEPPLEWHITE-GRAY DEPUTY LAMP

Fig. 199.



BIRAM
1849
Locked with Padlock

Fig. 197.

HOWAT'S PATENT DEFLECTOR.

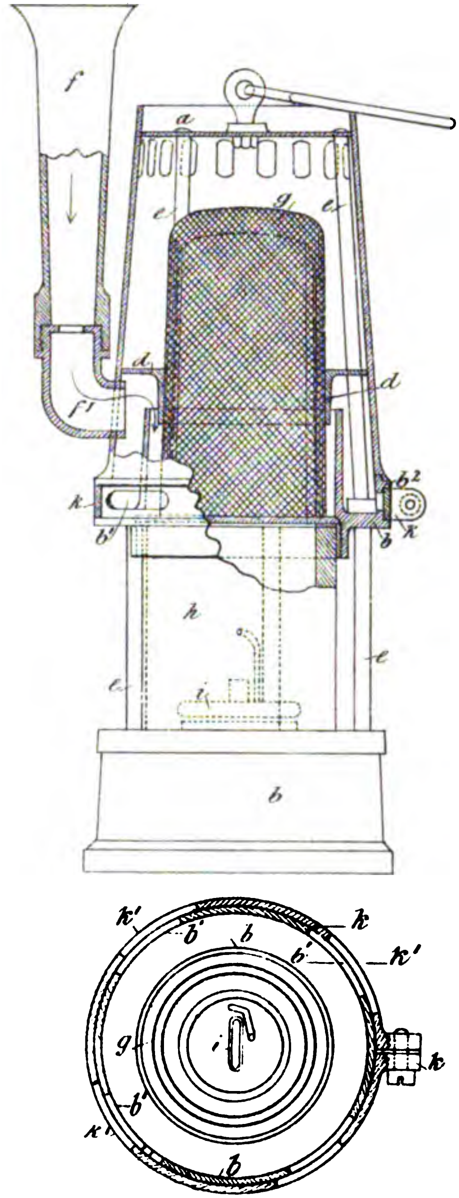


Fig. 200.

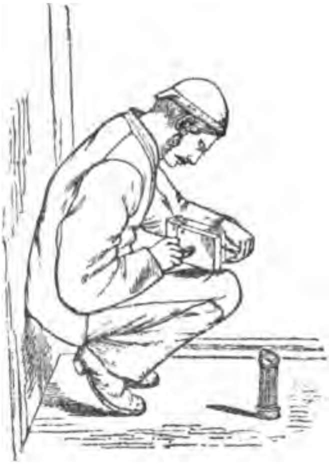


Fig. 201.

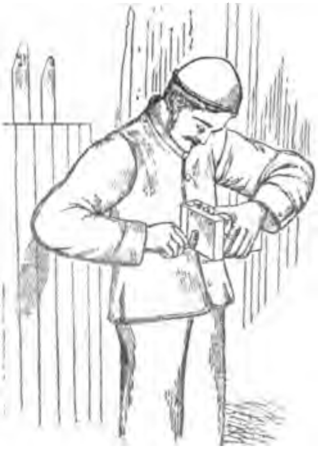
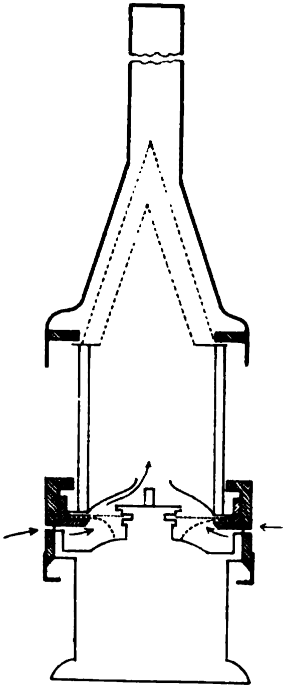
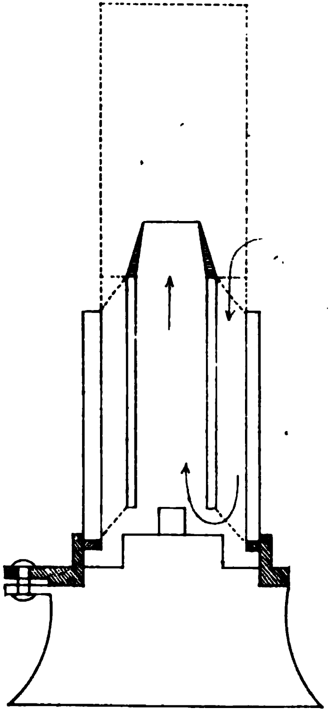


Fig. 202.



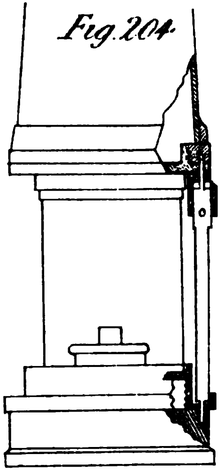
VON BUSCHMANN
"Shut off" Lamp

Fig. 203



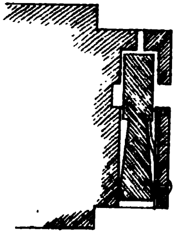
MACKWORTH
Lead Rivet

Fig. 204.



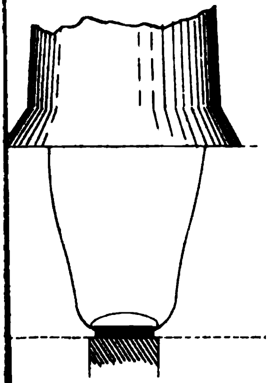
Ryder's patent locking bar for shielded Lamps. One third size.

Fig. 205



Morgan's lead rivet and spring lock. Two thirds size.

LIBRARY UNIVERSITY OF CALIFORNIA.

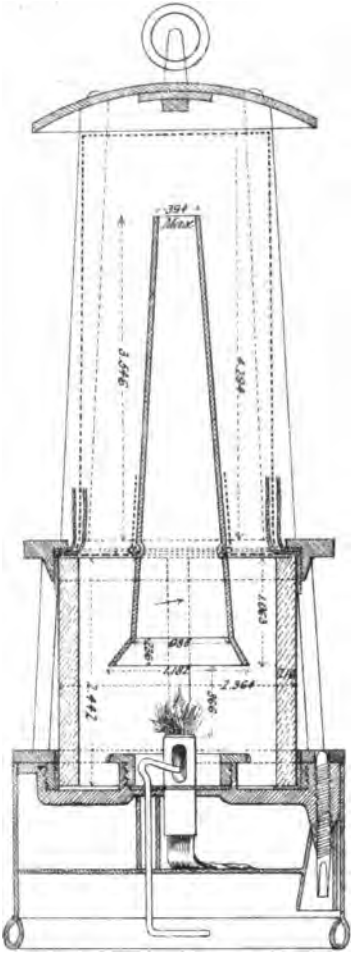


VI

5%

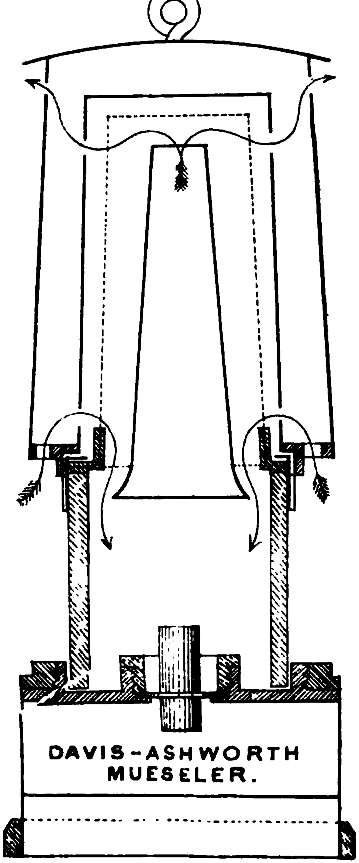
211.

Fig. 214



TYPICAL MUESELER LAMP

Fig. 215.



DAVIS-ASHWORTH MUESELER.

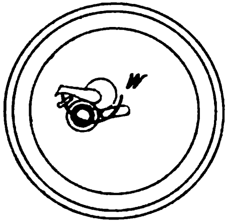
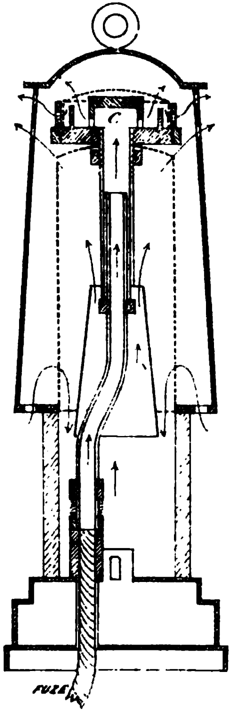


Fig. 216.—Plan.

HEATH & FROST'S
Shot-firing Lamp.

Fig. 216.



HEATH & FROST'S
Shot-firing Lamp

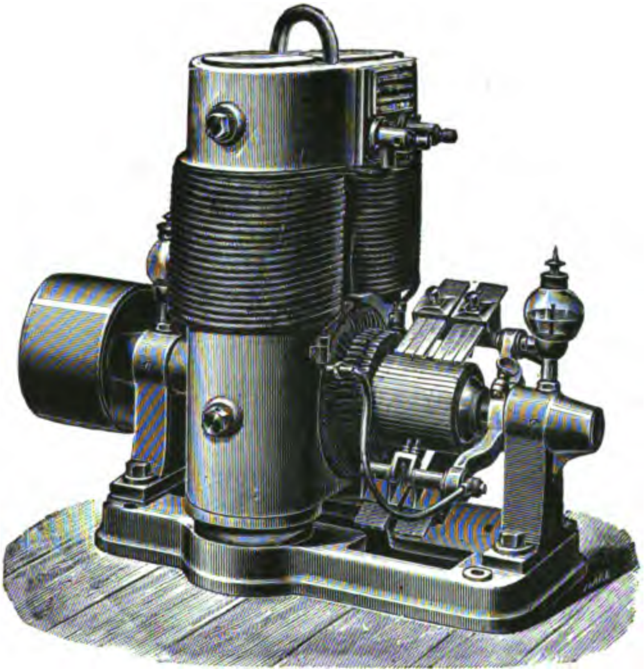


FIG. 217.—DYNAMO FOR ELECTRIC LIGHTING. (JOHN DAVIS & SON).

CHAPTER X.

STEAM, STEAM BOILERS, AND ENGINES.

548. What is steam?

Steam is an elastic and invisible fluid, or vaporised water, as water is liquefied ice.

549. At what temperature is water converted into steam?

With an ordinary barometric pressure, water will boil at a temperature of 212 degs. Fahrenheit, or at 100 degs. Centigrade, or 80 degs. of Reaumur's barometer.

550. Will adding or removing pressure make any difference in the boiling point of water?

Yes, if the pressure is decreased water will boil at a lower temperature, or if increased it will require a higher temperature; the boiling point of water depends upon the pressure to which it is subject, because the steam or vapour in forming has not only to lift a certain weight of water, but also the pressure of the atmosphere resting upon the surface of the water; hence it is possible to raise the temperature of the boiling point very considerably, and when this is done the steam formed is called high-pressure steam.

551. Will water evaporate at a lower temperature than 212 degs. Fahr.?

Yes, water will evaporate at very low temperatures if the pressure be reduced. Mr. Carre has invented an arrangement by which water can be frozen by its own evaporation. This arrangement consists simply of a powerful air-pump. On placing a bottle of water in connection with this apparatus, and pumping for a few minutes, the water will begin to boil rapidly, and the temperature of the water is reduced so far by its own evaporation as to freeze to a mass of ice.

552. If the pressure of the boiler amounts to 60 lb. per square inch, how will the boiling point be affected?

As the boiling point varies with the pressure of the atmosphere, so in precisely the same way, the pressure of the steam upon the surface of the water in a boiler will have a tendency to raise the boiling point, because the tension of the vapour has a great pressure to overcome before it can free itself from the water. The following figures show the pressure of steam at different temperatures, and the relative volume of cubic feet of steam to one of water:—

Pressure per square inch.	Temperature in Fahrenheit degrees.	Cubic feet of steam from one of water.
14·7	212·0	1642
30·0	250·4	838
60·0	292·7	437

There is therefore only one pressure and one density for each temperature; unless the whole of the water in the boiler be evaporated, and additional heat supplied to the steam, the state of saturation ceases, the steam becomes superheated, and the temperature and pressure are increased, while the density is not increased. Steam thus surcharged with heat approaches to a perfect gas.

553. In what way is steam condensed again to water?

By being brought in contact with a body cooler than itself.

554. Does salt water boil at the same temperature as fresh?

No, because the tension of the vapour has a greater resistance to overcome in passing from the water. Sea water containing one-thirtieth part salt, at a pressure of 15 lb. on the square inch, boils at a temperature of 100⅔ degs.; with one-fifteenth part salt, at 101⅓ degs.; with one-tenth part salt, at 102 degs. Cent.

555. What is understood by the specific heat of steam?

The specific heat of saturated steam is ·305 deg.; this is the amount by which the total heat of saturated steam is increased for each degree of temperature, or we may say the specific heat of steam is ·305 deg., that of water being unity, or it is 1·281, that of air being unity. The specific heat of a body signifies its capacity for heat.

556. What is the specific density of gaseous steam?

The specific density of gaseous steam has been found to be ·622, that of air being 1. That is to say, the weight of a cubic foot of gaseous steam is about five-eighths that of a cubic foot of air at the same pressure and temperature.

557. Can you give any particulars relating to the expansion of gaseous steam by heat?

The expansion of steam varies with the pressure at which the steam is produced. It has been found by experiment that all gases expand one-273rd part of their volume at 0 deg. Cent. for every degree of increase in temperature; thus, 273 volumes at 0 deg. Cent. will become 283 at 10 degs. Cent.

558. What is a boiler?

A boiler is a vessel or cauldron for boiling large quantities of liquor, but most commonly the term is used to denote a metallic vessel in which water is converted into steam by the action of fire, the steam being intended by its expansive force to give motion to the piston of a steam engine.

559. What forms of boilers are mostly used at collieries?

The most commonly used boilers at collieries are the cylindrical or egg-ended boiler and the Lancashire boiler. The former is a cylinder with spherical ends. It is placed with its axis nearly horizontal, and underneath, at one end, is placed the fire; it is enclosed in brickwork. The flame travels along the bottom of the boiler, beating directly on its under horizontal surface till it reaches the end furthest from the fire; after this, in some cases, the flame and hot air are conducted by a flue back to the front of the boiler, and they then travel along the other side to the chimney, the hot draught thus passing three times round the boiler, applying its heat to every part of the boiler that is covered with water.

560. Describe the Lancashire boiler.

It consists of a cylindrical shell with flat ends, and having two flues or tubes passing from end to end. In the flues firegrates are arranged, which together form a greater breadth of fire-room than the single grate of the Cornish boiler. This boiler is made from 6½ ft. to 8 ft. in diameter; and, in exceptional cases, 9 ft. or 10 ft. in diameter, with a length of from 28 ft. to 32 ft. If the shell is 6½ ft. diameter the two tubes would each be 2½ ft. diameter. In specifying a boiler of this description of the ordinary dimensions—say, 27 ft. long—the following are some of the necessary requirements:—The longitudinal seams to be double-riveted, 2 in. pitch, the circular seams to be single-riveted. None of the shells should be made taper, and the plates should be of the best Staffordshire iron, having the brand visible on the outside of each. The rivet-holes should be placed not less than ¾ in. from the edge of the plate. All the rivet-holes should be ¾ in. in diameter and the rivets of the best quality. They should be 2 in. apart, from centre to centre, all through the boiler; the front top plate over the fire should be of Lowmoor iron for 10 ft. in length.

561. Describe the Cornish boiler.

This form of boiler, which originated with Trevithick, is a cylinder with flat ends and a single tube passing from one end to the other. It is held to be a good rule that the diameter of the tube should be equal to half the diameter of the shell; thus, a boiler 6 ft. in diameter should have its tube 3 ft., and the tube should be so fixed as to leave 6 in. between the bottom of it and the bottom of the shell. Boilers of the Cornish type are made of various dimensions from 5 ft. to 7½ ft. in diameter, and from 20 ft. to 30 ft. long. The fireplace is placed within one end of the tube, where the grate is constructed, of the full width of the flue, and with a length usually one and a-half times the width. The draught is, or ought to be, carried along the tube to the end of the boiler, back underneath to the front, and on to the chimney by side flues.

562. How do you estimate the horse-power of a boiler?

The number of cubic feet of water evaporated per hour indicates the horse-power of the boiler; thus, a boiler which evaporates 40 cubic feet of water per hour is a 40-horse boiler. It must be remarked, however, that the system of calculation in practice with reference to boilers is somewhat elastic. The following rule is used for reckoning the horse-power of a Cornish boiler:—To the external diameter add the diameter of the tube in feet, multiply by length, add one-half to the product, and divide by ten.

$$\text{Therefore H.P.} = \frac{(D + d) \times L + \frac{1}{2}\{(D + d) \times L\}}{10} = \frac{3(D + d) \times L}{20}.$$

563. What weight of water per pound of coal consumed will a good boiler evaporate?

It will depend upon the class of boiler used, but a fair average would be about 8 lb. of water per pound of coal. Thus, if 190 lb. of coal are consumed per hour, there would be:—190 × 8 = 1,520 lb. of water evaporated; and assuming the unit of 30 lb. of steam per horse-power per hour, this would give a 50-horse power boiler. The useful effect of a boiler greatly depends upon the economy with which the steam is used. It has been ascertained by direct tests that, with the best class of engines in good condition, the steam from less than 18 lb. of water will furnish 1-horse power; on the other hand, a poorly constructed engine or in bad condition may require as much steam as will be generated from 60 lb. of water. The average experience, however, is 1-horse power from 30 lb. of water; or, approximately, one-half a cubic foot of water. Attention should be paid to the construction and proper working of the boiler; large sums of money have been uselessly spent in attempts to reduce the coal consumption, where it had been assumed that the engine alone was answerable for the waste of fuel, the real cause being in the boiler. Heavy incrustation in the interior, or the coating of the plates in the external flues with soot—both bad conductors of heat—are causes of much waste of fuel; or, it may be that the boiler has a bad draught, or is not properly stoked, or is uncovered and exposed to the weather, all of which will materially affect its efficiency. Steam may also be wasted at leaky joints and valves. In short, with better attention, there would often be great saving in fuel. The stoker should keep the firing thin all over the whole of the grate, not allowing the bars to be bare in any part, as this will cause an inrush of cold air and sudden contraction to the boiler plates. The dampers also should be regulated to allow only sufficient air for the combustion of the coal.

564. What would you do to prevent corrosion in a boiler?

Mr. Hannay, of Glasgow, claims to have discovered a preventive of corrosion and of the formation of scale in boilers, which he calls "electrogen." He says;—"The calcareous scale which forms in land boilers has been always a great source of trouble. The electrogen seems to have solved the problem; and to make it sufficiently active in fresh water the homœopathic principle is applied of *similia similibus curantur.* A small quantity of salt, the active corrosive agent in sea water, is made not only to cure the disease of corrosion which it actuates, but to stimulate an electric current which entirely disposes of incrustation. Sea water contains on an average thirty-two to thirty-eight parts of salt in 1,000." Mr. Hannay's homœopathic dose was half-an-ounce to a gallon, or four parts to 1,000; and, as no proportion less than eight times this amount has any effect on iron, no harm can be done to the boiler. With electrogen, it is claimed that boilers will work more than twice the usual time without any necessity for opening them, and that then the loose flakes of scale may be cleared out in a short time with a hose and a broom. Meantime, no thick scale being allowed to form, the coal consumed does its full work, and steam is made more freely.

565. Can you give a description of Henderson's mechanical stoker and self-cleaning furnace?

Figs. 219 and 220 illustrate this apparatus. The coals are thrown on by means of horizontal circular fans, which revolve in opposite directions towards the furnace, and are driven by frictional pulleys attached to the driving shaft, at the end of which is the belt pulley. On the centre driving shaft is a wheel working into a worm-wheel, B, attached to a vertical shaft on the top of which is another worm, A, which drives the crushers above

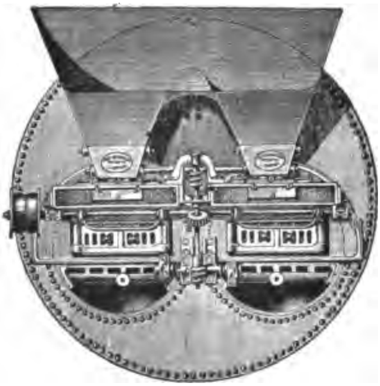


Fig. 219.

the fans. In front of these crushers there is a plate worked by a hand-screw from the outside for regulating the feed of fuel, and against this plate any large pieces of coal are broken. On the bottom of the vertical shaft is another worm and wheel for working the furnace bars, which rests on a rocker or cradle, by which means half the bars are moved up and down vertically, thus breaking up the clinker and keeping the fire open, while the other half of the bars travel backwards and forwards longitudinally, taking with them the clinker and refuse to the back of the furnace, which is deposited over the back end of the firebars into the combustion chamber, where the clinker forms a natural bridge. The clinker and refuse is taken out of this chamber, when cold, by opening a damper door at the back end under the bars. The bars in each furnace can be thrown out of gear at will by means of a thumb-screw. By means of a clutch the bars can be disconnected entirely from the machine, and the bars only left working. The firedoors are so constructed that hand firing can be carried on, should anything go wrong with the machine. A very interesting series of experiments have been conducted at the Wingate Grange Colliery, County Durham, to ascertain

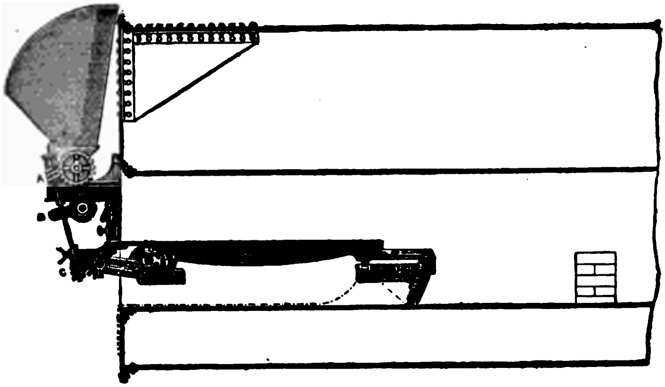


Fig. 220.

the comparative efficiency of hand firing against Henderson's patent. The boiler with which the experiments were made was of the Lancashire type, 28 ft. by 7 ft. 6 in., working at 35 lb. pressure during the day, and at 60 lb. pressure during the night. The hand firing tests were first made, and then the patent stoker was fitted up on the same boiler, and the experiments continued. The evaporative tests were made with two kinds of fuel—viz., rough small valued at 3s. 6d per ton, and duff valued at 2s. per ton. All the coals burnt were carefully weighed, and the ashes were also weighed, thus determining the percentage of ashes. The experiments were continued for forty-eight hours with each method respectively, and the results show that the cost of evaporating an equal quantity of water was reduced more than one-half, and the duty increased 23 per cent., the cost of fuel being reduced 1s. 6d. per ton.

566. Give a description of the Galloway boiler.

For a description of this boiler I cannot do better than give a copy of a specification received from Messrs. Galloway, which is as follows for a 60-horse boiler:—

The Shell.—The shell to be 28 ft. long by 7 ft. diameter, and to be made of best Snedshill plates ⅜ in. thick. The longitudinal seams to be double riveted, and to be crossed one-half the length of the plate, so as to avoid a continuous line of rivets. The edges of all the plates to be planed and fullered, not calked. Front end of shell to be provided with a solid welded ring of angle iron 3 in. by 3 in. by ½ in. for attachment of the ends.

The Flues.—The flues to consist of two furnaces, each 2 ft. 9½ in. in diameter, formed of solid welded rings of best Snedshill plates ⅜ in. thick, the transverse seams to be formed by flanging the plates in machine, and inserting a solid welded ring between the two flanges. The two furnaces to unite behind the fire-bridges into one flue, of best Snedshill plates, made in accordance with our 1875 patent, the flue being hollowed on its lower side to give more room for cleaning and examination, the necessary strength being obtained by bringing the tubes nearer together at their lower ends, and thus avoiding the necessity of the objectionably thick plates, which would otherwise be required for this part. This flue to be supported by means of thirty-three patent Galloway cone tubes, having a diameter of 10½ in. at the top, and 5½ in. at the bottom; the whole of these tubes to be interchangeable, and to have all their flanges square to the centre line of tube, thus putting less strain upon the iron in their manufacture and thereby allowing a better job to be made.

End Plates.—The boiler ends each to be in one piece, ½ in. thick, of the best Snedshill iron. The front plate to be securely attached to angle iron of shell, and the back end plate to be flanged. These end plates to be efficiently stayed by means of suitable gusset plates which shall be fastened by double angle iron to shell of boiler; these stays shall not be brought down too near the top of furnaces, but sufficient space shall be allowed for expansion.

Manholes.—One cast iron manhole of large size to be fixed on the top of boiler, and one of smaller size fixed on the front end plate below the flues, both to be riveted on and to be faced across the whole surface of their flanges; cast iron covers for the same to be provided with suitable bolts.

Testing.—Before leaving the works the boiler shall be tested with a water pressure of 100 lb. per square inch, and a certificate of such test having been made shall be furnished.

MOUNTINGS FOR BOILERS.

Furnace Fittings.—A set of suitable fire frames and doors to be fitted on to the front end of the boiler, and each door shall be provided with a sliding shutter, for the admission of a proper quantity of air for the prevention of smoke, also cast iron hearth plates, bearing bars, firebars, of suitable length, cast iron damper and frame and ash-pit frame plates.

Fusible Plugs.—An approved fusible plug shall be placed on the top of each furnace.

Blow-off Cock.—One blow-off cock to be supplied with solid bottom and pack gland, having a flange at each end; also a suitable elbow pipe to be furnished for attaching the cock to the block previously riveted on to the boiler.

Feed Valve.—A 2½ in. check feed valve shall be provided, the valve to be loose from the spindle so as to act as a check or non-return valve, and to be set down by means of a handwheel and screw.

Safety Valve.—One 4 in. safety valve of the most approved construction.

Steam Nozzle.—One 7 in. junction valve fitted up with gunmetal valve and seating, packed gland, handwheel, &c.

Anti-priming Pipe.—A cast iron anti-priming pipe to be fixed inside the boiler, and attached to lower end of the above valve.

Water-gauge.—One set of brass fittings for glass water-gauge with two glass tubes for the same.

Steam-gauge.—One 7 in. steam-pressure gauge of best construction, with siphon.

The improved boiler in the above specification possesses advantages over the Galloway boiler as originally constructed, having a larger amount of heating surface, stronger back flue, and greater facilities for cleaning and repairs. The well-known brand of Snedshill iron is the quality of iron almost invariably used in the construction of the Galloway boiler, and it has, doubtless, to a certain extent increased their reputation for durability and satisfactory working. Boiler, precisely similar in every way, can be constructed of best Staffordshire iron.

567. Can you give a table of the heating surface and horse-power per cubic foot of water evaporated, &c., and other details of some of the principal boilers now manufactured?

The table given on page 342 is extracted from the official list of the various boilers in use at the Philadelphia Exhibition, 1876, from which it will be seen that the Galloway boiler gave the most economical results.

Description of Boiler.	Heating surface in square feet.	Horse-power at 1 cubic foot of water evaporated per hour.	Lb. of water evaporated.			Percentage of water in steam.	Lb. coal burnt.		Temperature of gases leaving boiler.	Cubic feet of water space per horse-power.	Cubic feet of steam space per horse-power.
			Total.	Per hour.	At 212 degs. per lb. combustible.		Per hour.	Per square foot of grate per hour.			
Galloway	973	41·64	20,824	2,603	11·72	·57	283	7·269	324	14·10	4·04
Root	1,590	54·29	27,146	3,393	11·565	not taken	381	9·09	393	2·29	·89
Firmenich	1,078	26·46	13,233	1,654	11·53	not taken	185	11·79	415	4·08	2·63
Lowe	774	21·45	10,729	1,341	11·489	not taken	153	6·805	332	9·02	2·63
Babcock.........	1,680	62·70	31,358	3,919	11·489	3·24	444	9·77	295	3·74	2·20
Andrews	540	18·94	9,469	1,183	10·513	not taken	148	not taken	419	4·14	1·29
Wiegand	1,355	68·08	34,042	4,255	10·461	not taken	517	12·32	523	2·66	·64
Anderson	1,135	44·44	22,230	2,778	10·255	not taken	350	9·747	417	1·43	1·28
Kelly	662	37·41	18,710	2,338	10·099	5·97	291	10·82	not taken	1·91	·68
Harrison	900	36·57	18,285	2,285	10·022	1·11	284	12·36	517	1·93	·80
Pierce............	200	23·74	11,876	1,485	9·818	5·53	199	7·99	373	·65	1·64
Exeter	1,525	32·65	16,334	2,041	9·765	4·63	280	9·35	429	2·66	1·43
Rogers & Black	399	21·13	10,564	1,320	9·31	2·68	181	8·05	571	1·71	1·17

568. In a Lancashire or Galloway boiler, through which flue would you carry the flame first—the bottom flue or the two side flues—and why?

After the flame has left the tubes in which the fire-grates are placed, I would first pass it through the bottom flue which runs underneath the boiler to the front end of the boiler, then split the flame and pass it along the two side flues, then out of these into the chimney. By first passing the flame underneath, the bottom of the boiler gets heated, the result being a more equal expansion of the boiler plates than if the flame first passed along the two side flues, in which case the middle of the boiler would get all the heat and the bottom part scarcely any, causing a very unequal expansion.

569. What is meant by the indicated horse-power of a boiler?

The indicated horse-power is the power required to raise 33,000 lb. 1 foot high per minute. It can easily be measured by anyone conversant with the steam engine.

570. Which do you consider the best and safest boiler for colliery purposes—the Lancashire or the egg-end—and why?

The boiler I would recommend for colliery purposes generally is the Galloway boiler, or the Lancashire boiler with Galloway's patent tubes. The egg-end boilers are very dangerous; the heat being applied to the bottom side, the expansion is very unequal, and what is called a seam-rent or cracking of the plates from rivet-hole to rivet-hole is sometimes the consequence, not only in the longitudinal seams but also in the transverse joints—that is, a crack round the boiler. The greater number of explosions of egg-ended boilers have been caused by this. With these boilers winding engines are liable to break down, owing to water getting into the cylinder, and also there is great wear and tear on the piston and valves, owing to dirt being carried over with the steam. Both these things occur if the boiler is regularly worked with very dirty water, and if the water is carried too high in the boiler. The liability, however, to prime is very much reduced in the Galloway boiler owing to the rapid circulation of water, caused by the introduction of the tubes. The plain egg-ended boiler has no circulation at all, the whole of the water lying in bulk, and over the fire, where the heat is intense, it is just boiled up and is very apt to fly away with the steam along the main pipe to the engine, carrying with it also the dirt. The Galloway boiler also is invariably provided with an anti-priming pipe, as will be seen by the specification. It is attached to the lower end of the stop valve, extending longitudinally inside the boiler. It is 5 or 6 ft. long, and is perforated on the top side with a number of small holes; through these holes the steam enters the pipe and is broken up. Any water that is carried up is deposited in this pipe and flows down through the hole provided at each end of the anti-priming pipe, back again to the boiler, and the steam which goes along the main pipe is thus rendered entirely free from water and dirt.

571. Can you describe the usual fittings to colliery boilers, their utility and the requirements of the Coal Mines Regulation Act, 1887, with reference to them?

By the thirty-second general rule it is enacted that "each steam boiler, whether separate or one of a range, shall have attached to it a proper safety valve, and also a proper steam-gauge and water-gauge, to show respectively the pressure of steam and the height of water in each boiler." *Steam-gauge*: This is constructed in many ways, sometimes consisting of a spring so arranged as to indicate the rise and fall of the pressure, the steam being allowed to act upon the spring by passing along a pipe inserted in the boiler to a convenient place where the gauge is fixed. The scale on the case containing the spring is graduated by experiments. This is done for different pressures, the intermediate pressure being interpolated. *Safety Valve*: This is required on every boiler. The valve must be kept from gagging, and when the pressure in the boiler overcomes the weight of the valve lever and suspended weight, steam will blow off.

572. If, on examination, boilers are found to be thin, what means would you adopt to prevent accidents?

Reduce the pressure on the safety valve.

573. If the safety valve on your steam boiler is 4 in. diameter, and the steam blows off at 50 lb., and length of lever 36 in. and fulcrum 4 in. long, what weight would have to be attached to the end of the lever, reckoning lever and valve to weigh $5\frac{1}{2}$ lb.?

The weight to be attached to the end of the lever would be found as follows:—$4^2 \times \cdot7854 = 12\cdot5664$ in. area of valve $\times$ 50 lb. $= 628\cdot3200 - 5\cdot5 = 622\cdot82 \times 4 = \frac{2{,}491\cdot2800}{36} = 69\cdot2$ lb. weight to be attached to end of lever, or

Let W = weight attached to end of lever.
„ w = „ of valve and lever.
„ L = length of lever from fulcrum to weight.
„ l = „ „ „ „ valve spindle.
„ A = area of valve in square inches.
„ P = pressure of steam per square inch.

$$\because \; W = \frac{P \times A \times l - w}{L} \text{ lb.}$$

574. Give a few details, with rules for finding the pressure on safety valve and weights to be attached, &c.

If the pressure on a safety valve is to be obtained by means of a weight or spring balance, through the intervention of a lever, the accumulation of effect by the lever is as the number of times its length from centre of rotation to weight or spring balance exceeds the distance from centre of rotation to centre of valve, but in calculation of results the weight of the valve and action of the lever, or effect of pressure produced upon the valve by the lever's gravity and general magnitude must be taken into account; hence, the following example for general application:—Suppose the diameter of a valve = $3\frac{3}{4}$ in. Pressure required per square in., 40 lb. Length of lever from centre of rotation, 27½ in. Distance f of rotation to centre of valve, 4 in. Action of le weight of valve included, 5½ lb. Then $3{\cdot}75^2 \times {\cdot}7$ 11·0446 in. area of valve, and $11{\cdot}0446 \times 40 = 441{\cdot}7$ total pressure required.

(1.) To find the weight which will be required to produ that pressure at the given distance of 27½ in. from centr of rotation:—$441{\cdot}784 - 5{\cdot}5 = \frac{436{\cdot}284 \times 4}{27{\cdot}5} = \frac{1{,}745{\cdot}136}{27{\cdot}5} =$ 63·46 lb., the weight to be attached or pressure indicated by a spring balance.

(2.) The weight being given, to find at what distance from the centre of rotation it must be placed to produce the amount of pressure:—$\frac{436{\cdot}284 \times 4}{63{\cdot}46} = \frac{1{,}745{\cdot}136}{63{\cdot}46} =$ 27·5 in.

(3.) The weight and distance from lever's centre of rotation being given, also distance of valve, to find the pressure on the valve:—$\frac{63{\cdot}46 \times 27{\cdot}5}{4} = \frac{1{,}745{\cdot}136}{4} =$ $436{\cdot}284 + 5{\cdot}5 = 441{\cdot}784$ lb.

575. Find the situation of the fulcrum along a lever 15 ft. in length, on which 2½ cwt. placed at one end may equipoise 30 cwt. at the other, the weight of the lever not taken into account.

$15 \times 2{\cdot}5 = 37{\cdot}5$; then $2{\cdot}5 + 30 = 32{\cdot}5$; $\frac{37{\cdot}5}{32{\cdot}5} = 1{\cdot}154$ distance in feet from the end of lever where the fulcrum is to be placed.

576. At what height should the water stand in a Galloway boiler?

From 6 in. to 8 in. above the tubes.

577. When water in the boiler is allowed to get too low, what may happen?

The boiler will burn or burst.

578. When the water in the boiler has been allowed to sink below the working level, what would you do?

I should cover the fire with wet ashes or slack, then close the damper, but under no circumstances would I disturb the fire, or turn on the feed-water, or open the fire-doors, or tamper with the safety valve, or start the engine if standing.

579. What questions relating to his boilers should an intelligent stoker be always able to answer?

I consider the stoker should always know when last the inside of the boiler was examined; when the safety valve was last raised, and whether it and the steam-gauge agree; whether the steam-gauge is correct; if the boiler is clean; if the blow-cock is tight, or whether hot water is blowing out of it unperceived; whether the gauge-cocks are tight—not merely depending upon the water-glass, but from personal trial; if the water-gauge is properly connected; how much coal is consumed daily; whether there are any soft patches on the boiler in the furnace; whether the water supply is regular or intermittent; if the boiler has been run full of water, and then the feed entirely shut off; what ought to be done with a boiler that primes regularly; whether there is a damper in the smoke stack and if it is ever used. A good stoker will attend to the air supply, and will see that the coal used is of an advantageous and economical size, with reference to the draught. He will know the difference between a live fire and a dead one, and that the latter may look red, but have no life or steam-raising virtue. He will also remember that he is entrusted with an instrument of tremendous force, and whether for good or evil depends largely on his care.

580. Is it dangerous to enter a boiler which has been standing for some time, after the water has been blown out? If so, what precautions should be taken?

Yes; it is dangerous, especially if the boiler has been fed with dirty or muddy water, carbonic acid gas being sometimes generated from the mud and the residuum of dirty water. As a precaution, after the water is blown out, I would leave the blow-cock open, and open the gauge-cocks before taking the manhole lid off, to ensure a circulation of fresh air.

581. Can you give a rule for calculating the bursting pressure per square inch of boilers?

The ultimate tensile strength in tons per square inch of section of metal is equal to the product of the diameter multiplied by the bursting pressure per square inch, divided by the thickness of metal and by 4,480. Mr. L. E. Fletcher tested a Lancashire boiler 7 ft. in diameter, made of $\frac{7}{16}$ in. plates. It bore a pressure of 310 lb. per square inch, when it failed at one end at the longitudinal seam which was double riveted. In this case, applying the above rule, the ultimate tensile strength would be equal to $\frac{84 \text{ in.} \times 310 \text{ lb.}}{\cdot 4705 \text{ thickness} \times 4{,}480}$ $= 12{\cdot}35$ tons per square inch of section of the entire plate. Again, a cylindrical boiler 11 ft. 3 in. diameter, made of $\frac{3}{4}$ in. plates, double-riveted, was burst by a hydraulic pressure of 230 lb. per square inch; then by rule $\frac{125 \text{ in.} \times 230 \text{ lb.}}{\cdot 75 \text{ thickness} \times 4{,}480} = 9{\cdot}241$ tons per square inch of section of the solid plate.

582. What qualities should good boiler-plate iron possess?

Engineers say the tensile strength of good boiler plate iron should not be less than 40,000 lb. per square inch, its elastic resistance should not be less than 25,000 lb. per square inch, and its contractibility 15 per cent.

583. How are boilers usually tested?

Either by hydraulic or by the hammer test. In the hydraulic test the boiler is filled with water, and then by means of a hand force-pump the pressure is raised up to what the boiler is supposed to withstand, the working pressure under steam being usually about two-thirds of the tested pressure—that, a boiler required to work at 60 lb. pressure is tested up to 90 lb. per square inch. The hammer test consists of tapping with a hammer all accessible parts of the boiler, such as the shell, crown sheets, flues and back and front connections, and an engineer experienced in this mode of testing can tell from the sound produced whether the part struck is sound or not. The writer is of opinion that the hammer test should only be used by thoroughly experienced men, and that the hydraulic test should not be carried beyond the pressure at which the boiler is required to work.

584. A boiler plate 9 ft. 6 in. long is to form the tube of a boiler having only one seam of rivets—that is, the one plate to form the whole circumference of the cylinder. What will be the diameter of the cylinder when the plate is rolled up?

The rule is:—Multiply the length of the plate by ·31831, and the result will be the diameter of the cylinder. Example: 9·5 × ·31831 = 3 ft. diameter. No allowance is made by this rule for lap.

585. In fixing a boiler on its seating, which should be the lower end—the front or back end—and why?

I would have the front end about 1 in. or 1½ in. the lower, for two reasons—first, when the boiler is being cleaned any dirt or sludge will fall to the front end and pass through the blow-off tap; second, because every boiler should have the blow-off tap open at least once in twenty-four hours, for a few seconds, for the purpose of blowing any sludge out that may have accumulated during the day.

586. In putting in new boilers, what is the usual price paid to bricklayers for brickwork?

The usual price given for putting in brickwork is 2s. 6d. per cubic yard, measuring all hollow places, such as side flues, &c., in.

587. What is the effect of sediment or incrustation forming in a boiler; and is any danger likely to arise from it?

The effect of sediment or incrustation forming on the inside of a boiler is as follows:—As gypsum, lime, salt, &c., are deposited internally upon the plates of a boiler, they form a solid crust—sometimes very rapidly. Since the incrustation consists of earths, it is a very bad conductor of heat. The boiler plates may consequently become red hot, without the heat penetrating the deposit. When the boiler plates become red hot, the incrustation will probably separate from the iron, through the latter expanding more than the former, and the water will reach the plates, and a sudden generation of steam in greater quantities than the safety valve will pass will cause a tremendous explosion.

588. What are some of the most important duties of a fireman or boiler-tenter?

Before lighting the fires, to see there is plenty of water in the boiler, and ascertain whether all the valves and cocks are in working order. In getting up steam from cold water, to do it slowly, as when it is done too rapidly it injures the boiler. To keep the bars clean and free from clinkers, and always covered with fuel. With small coal, to keep a fire from 4 in. to 7 in. thick, or as thick as the nature of the coal will allow. To regulate the feed supply so as to keep the water at one level, by adjusting the feed stop valve to the proper height. To keep the boiler mountings clean and bright, the steam and water passages clear, the valves tight, and all joints good. To test the safety valves every morning and occasionally during the day; never to add extra weight to prevent escape of steam. Before emptying a boiler of hot water or steam, to draw out the fire. To clean the boilers at least once a month (some require cleaning oftener), using proper tools so that the scale may be got off.

589. What is a water heater? Explain its use.

In principle a water heater is a cylindrical boiler from 10 ft. to 15 ft. long, and from 4 ft. to 5 ft. in diameter. The feed water passes through the heater backwards and forwards three or four times, by means of 2 in. gas pipes, before going into the boilers; the exhaust steam from the engines is carried into the heater and heats the water while it is passing through the pipes, which results in economy in fuel.

590. Which method do you consider best for feeding boilers—the injector, or by a water heater through which the water is forced by boiler pumps?

I consider the injector best, as all the steam used to work it is given back to the boiler in the shape of hot water, and no back pressure is put on the engine, as is the case when boilers are fed with the water heater.

591. Explain the principle of the injector and how it is that steam at 70 lb. pressure can force its way and carry a rapid current of water with it into a boiler under the same pressure.

The following sketch (fig. 221) will serve to explain the principle of the injector. A is the end of a boiler partly filled with water; B is the water line; C is a pipe into which steam is admitted; the end of this pipe forms a cone at D, which is enclosed in a larger cone, E. In the cone, D, there is a pointed plug which can be raised or lowered so as to increase or diminish the area of the orifice of the cone, D. F is the water-pipe leading to the reservoir, and admitting water into the outer cone, E. G is the feed-pipe leading to the boiler under water level. When steam is started through the pipe C, and at the same time the right quantity of water is started through the pipe F, the mixture of steam and water will pass through the neck, G, with such force as to enter the boiler. Globe valves, of course, are supposed to be placed at, say, C for the admission of steam, at F for the admission of water, and a back-pressure valve at about H to retain the water in the boiler. Water is now supposed to be in the reservoir, K, but only air is in the pipe F. Now, when steam passes the bell-

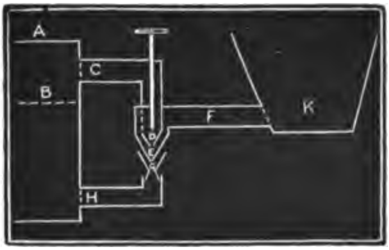


Fig. 221.

shaped funnel, D, it sucks with it the air in the pipe F, and the water in the reservoir rushes in to take the place of the air. As soon as the water enters the funnel and comes in contact with the steam, it is forced through the neck, G. It is well understood that a simple jet of steam issuing from D could never drive back a jet of water issuing from G under the same pressure. But when the injector is in operation as described above, the water absorbs a certain amount of heat from the steam, and this heat and condensation is a source of energy directly available for doing work. This is so, because the velocity of the steam issuing from D is many times greater than that of the water issuing under the same pressure at G when the back-pressure valve is open. The moment the steam enters the water in the large funnel, G, it is condensed and other steam rushes into the vacuum formed. But the thin stream of condensed steam still moves at a higher velocity than water coming out of the boiler at G is capable of, because it is continually being pounded on from behind by the very rapidly moving steam, though it loses some of its velocity consequent on the water it carries with it, and for this reason the quantity of water must be regulated, so that the condensed steam and the water with which it is mixed will always have a greater velocity than the water in the boiler would have if it were allowed to pass out through the pipe G without interruption. Then, so long as the velocity is greater, it will overcome the water in the pipe G, and enter the boiler. If the pipes C and G are of the same size, as they usually are, and the steam did not condense on entering the water, the steam could not move any faster than, and even not so fast as the water in the pipe H, and the pressure would not be any greater, but as the steam condenses into a much smaller jet of water which is constantly pounded on by fresh steam, the thin stream of water must attain the same velocity as the steam itself except as it is retarded by the addition of the water from the pipe F. Too much water will retard it to too great an extent and prevent it from entering the boiler; therefore the water is regulated so that the necessary velocity is always maintained.

592. Give a description of a good injector.

The exhaust injector (Hamer, Metcalfe and Davies's patent) is the best and most economical injector that has come under my notice. The following is a detailed description :—The exhaust steam injector, like the "Giffard," has three cones—the steam cone, the combining, mixing or condensing cone, as it is variously termed, and the delivery cone—but the proportions of the various parts, cones and nozzles, differ from those of the "Giffard" injector, and it is by the adoption of these proportions that the exhaust injector is enabled to feed a boiler with exhaust steam against a pressure of 70 lb. per square inch. The combining cone, D, also differs from that of the "Giffard" injector, it being split from the nozzle upwards, and is technically known as the "split" or "flap" nozzle, N, one-half being hinged to a pin at its upper end. It is to this hinged part of the combining cone, which is called the flap, that the automatic or self-starting action of the exhaust injector is due. When the injector is not at work, the hinged flap of the combining cone, or split nozzle, hangs open. This allows the supply water to flow, by the force of gravity, through the combination cone full bore at its greatest diameter. This flow of water clears the injector and water pipes of air, and then by the action of the current of water the air in the branch exhaust steam pipe (to which the injector is connected) is rarefied, and a small quantity of exhaust steam is drawn into the combining cone and condensed, and a slight vacuum is formed; more steam is then drawn into the combining cone, which is, in its turn, condensed, and a better vacuum results. The supply water and exhaust steam then rush into the improved vacuum, condensing the steam in the combining cone, and producing a vacuum nearly equal to that due to the pressure of the atmosphere. The instant the vacuum is formed, the hinged flap of the combining cone is sucked to its seat (the click of the flap can be distinctly heard) and is firmly held there as long as the

References.—A is the steam supply, B the steam cone, and S the steam nozzle; C is the water supply, and T the water nozzle; D is the combining cone, E the jet nozzle, and F the throat; K is the spindle, R the regulator, G the overflow.

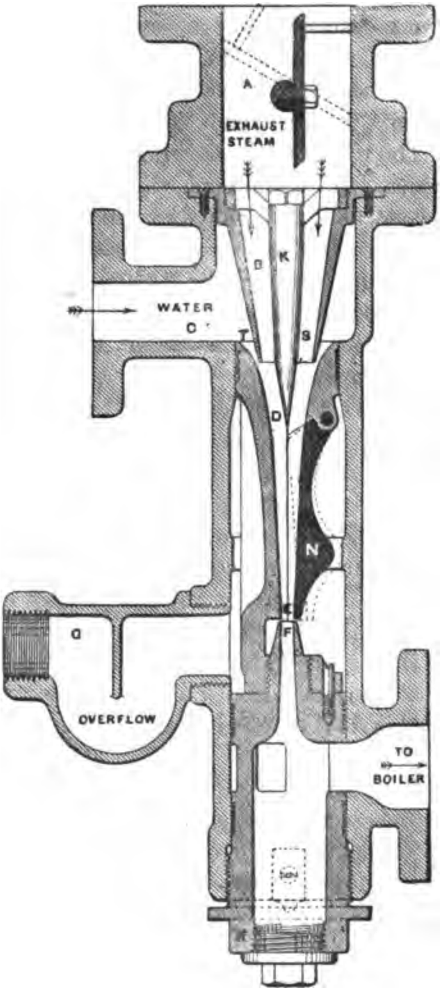


Fig. 222.

injector is in action, the combining cone and its nozzle acting precisely as if formed in one piece, similar to the other cones. The overflow then ceases and the injector is at work. These injectors, in my judgment, are marvels of economy and simplicity. The exhaust injector can be worked with the exhaust steam of any engine (a fan engine is the best at a colliery, as the exhaust steam is uniform) and it reduces back pressure upon the engine, whereas the feed-water heater increases back pressure. The exhaust injector heats the feed water to a temperature of about 190 degs. Fahr.

593. With a boiler pressure of 100 lb. and the normal temperature of the feed water before heating 60 degs., what economy of fuel would be effected by heating the feed to 250 degs.?

The heat in a pound of steam of 100 lb. pressure measured from 32 degs. is 1,181 degs.—that is, 1,181 units of heat are used up in converting 1 lb. of water at 32 degs. into steam of 100 lb. pressure. By heating the feed water from 60 degs. to 250 degs. the number of heat units taken up in the water will be 1,181; then 250 − 32 = 218, and 1,181 − 218 = 963; the economy of fuel will be in the inverse ratio of 963 to 1,149, or a little over 17 per cent.

594. What material would you use in felting or covering your boilers to keep in the heat?

I would first cover the boilers with sawdust to a thickness of about 2 in., and then put on a ring of 4½ in. of bricks and mortar.

595. What is a steam engine?

A mechanical contrivance having steam for its motive power. There are numerous varieties of steam engines, but they may be classed under two heads, viz., high-pressure or non-condensing engines, and condensing engines.

596. Can you give a rule for calculating the nominal horse-power of condensing and non-condensing steam engines?

Approximate rule for calculating the nominal horse-power of engines: For non-condensing or high-pressure, square diameter of cylinder in inches and divide by ten;

for condensing, square diameter of cylinder in inches and divide by thirty.

597. Explain the difference between a high-pressure and a condensing or low-pressure engine.

A high-pressure engine has no condenser or air-pump, but works by the excess pressure of the steam above that of the atmosphere. In a condensing engine, the vacuum caused by the condenser and air-pump, if they be in good working order, is equal to a pressure of 13½ lb. on the side of the piston opposite to that of the steam.

598. How is steam admitted into the cylinder?

By means of valves which are worked by eccentrics.

599. Explain how a slide valve is worked by an eccentric.

The eccentric is a circular plate attached to the crank shaft, not in the centre but outside, thus making the eccentric really a crank, having for its throw the distance between the centre of the crank shaft and the centre of the eccentric.

600. What is understood when it is said the engine is working expansively?

When the pressure of the steam admitted to the cylinder is sufficiently high, the steam is not allowed to flow into the cylinder for the whole of the stroke, but the supply is cut off at some distance from the end of the stroke. The consequence is that for the remainder of the stroke, the steam, already shut into the cylinder, acts on the piston simply by its own elastic or expansive force.

601. Explain the action of the slide valve and cut-off valve?

The plain slide valve works with little or no expansion and uses much steam. The adjustable cut-off valve works with a fixed ratio of expansion determined by the judgment of the engineer. In the automatic cut-off valve the ratio of expansion is determined by the engine itself—that is, it meets the requirements of the load or work of the engine at any given instant of time, and is the most economical of the three.

602. What is a throttle or stop valve?

The throttle valve is fixed in the steam pipes to admit steam to or shut-off steam from the engine. It should be noted that the actual area of the throttle valve should not be less than the sectional area of the main steam pipes, independent of all ribs, guides, &c., in the seat of the valve ?

603. What is meant by a compound engine ?

An engine in which the steam performs the greater part of its expansion in a second cylinder of much larger diameter than the first cylinder. The expanding steam, whilst its pressure diminishes, acts upon a larger area of piston, and thus, by a compensation, greater steadiness of driving power is obtained. The steam from the first cylinder, after having acted on the piston for one stroke, is conducted into the second cylinder, where it continues to work expansively.

604. Describe the action of the double-acting condensing engine.

The piston receives its motion from the steam, which is admitted first from the boiler into the steam-chest. The steam-chest contains two passages, and is connected at top and bottom with the cylinder, but the up-and-down motion of the slide valve always shuts one of these, and permits the entrance of the steam to one side of the piston only. As soon as the piston reaches the top it lifts the slide valve, admits the steam to the upper side, which drives the piston downwards; the steam then escapes or enters the condenser, and is there, by the injection of cold water condensed. In the high-pressure engine the working steam has always to exceed the atmospheric pressure, and so requires greater tension. The water accumulated in the condenser escapes near the bottom by means of a valve into the bottom of the air-pump, which lifts and carries away the condensed water and air. A portion of the warm water thus lifted from the condenser is taken up by the feed pump, which forces it into the boiler. Another pump, called the cold-water pump, worked by the regular action of the engines, supplies a reservoir round the condenser with cold water, from which reservoir the necessary quantity of cold water enters the condenser, the quantity being regulated by a cock.

605. Describe the condenser and air-pump of a condensing engine.

The condenser of an engine is the part to which the used steam escapes from the cylinder. The steam is there condensed by a jet of cold water. Steam and water always contain a certain amount of air, which remains in the condenser after the condensation of the steam, and would, if not pumped out, destroy the vacuum. This air is pumped out by means of the air-pump.

606. How does the steam act on a Cornish or single-acting condensing engine; also on the double-acting condensing engine?

In single-acting or Cornish pumping engines the steam is admitted to only one end of the cylinder. This brings up the weight attached, or pump-rods, to the outer end of the beam, where there is a counterpoise sufficiently heavy to draw the piston to the upper end of the cylinder after it has been forced down by the pressure of the steam on its upper surface; the used steam goes to the condenser. In the double-acting condensing engine the steam acts on both sides of the piston, and after having done its work is likewise allowed to escape to the condenser.

607. What is meant by an atmospheric engine?

The atmospheric engine is similar to the single-acting condensing engine, but instead of the steam acting on the top side of the piston to force it down, it acts on the bottom side and forces it up; it is then condensed as in the other condensing engines; the cylinder having no cover at the top end, thus leaving it open to the atmosphere, the piston is forced down by the atmospheric pressure.

608. What is a vacuum?

Theoretically an absolutely empty space; but for practical purposes enclosed space in which the tension of the occupying gas is very small compared with the ordinary tension of the atmosphere outside. The best known vacuum is the vacant space above the mercury in a barometer.

609. Explain the factor of horse-power.

It is a multiplier employed in calculating the horse-power of an engine, the horse-power being equal to the mean effective pressure of steam per square inch, the area of the piston in inches, the length of stroke in feet, and the number of single strokes per minute divided by 33,000; or, in other words, the factor is got by multiplying the piston area in square inches by the mean pressure per square inch and by the piston travel in feet per minute, and dividing the product by 33,000. By the table on page 360, which appeared in the *Mechanical Journal*, the exact horse-power of an engine of any of the cylinder diameters given, running at any piston speed quoted, may be calculated by multiplying the factor by the mean effective pressure of steam.

610. Find the horse-power of a steam engine cylinder 30 in. in diameter, stroke 4 ft., making 40 revolutions per minute, and 30 lb. steam pressure; also give the effective horse-power of the same, allowing two-tenths for loss by friction.

The following is the rule to find the horse-power of a steam engine :—

$$\frac{30^2 \times \cdot 7854 \times 4 \times 40 \times 30}{33{,}000} = 102\tfrac{3}{4}\text{-horse power.}$$

The above is the horse-power, but two-tenths being lost by friction, the effective horse-power will be :—

$$\frac{102\tfrac{3}{4} \times 2}{10} = 20{\cdot}55\text{-horse power lost by friction;}$$

then, $102{\cdot}75 - 20{\cdot}55 = 82{\cdot}2$-horse power effective.

611. Find the horse-power of a capstan engine or steam crab, the engine to have two cylinders 10 in. diameter; stroke 30 in.; revolutions of engine per minute 35; pressure of steam, 40 lb.; the first pinion on crank shaft 15 teeth working into spur wheel with 70 teeth, the second pinion 20 teeth working into spur wheel of 80 teeth, on the drum shaft.

TABLE OF FACTORS OF HORSE POWER FOR CYLINDERS OF VARIOUS DIAMETERS AT DIFFERENT PISTON SPEEDS.*

Dia.	Area.	Piston Speeds in Feet per Minute.							
		200	225	250	275	300	350	400	450
6	28·27	·17133	·19275	·21416	·23558	·257	·29985	·34266	·38551
7	38·48	·23321	·26237	·29151	·32066	·34981	·40771	·46642	·52475
8	50·27	·30466	·34216	·38083	·41891	·457	·52259	·60933	·68553
9	63·62	·38557	·43378	·48196	·53016	·57836	·67479	·77125	·86758
10	78·54	·47600	·53552	·59500	·64550	·714	·83305	·95078	1·0710
12	113·10	·68545	·77110	·85681	·94250	1·0283	1·1996	1·3709	1·5423
14	153·94	·92690	1·04963	1·16621	1·28283	1·3994	1·6327	1·8658	2·0992
15	176·72	1·07103	1·20496	1·33878	1·47266	1·6065	1·8744	2·1420	2·4099
16	201·06	1·21854	1·37092	1·52318	1·67550	1·9096	2·1325	2·4370	2·7418
18	254·47	1·54224	1·73510	1·92780	2·12058	2·3133	2·6990	3·0844	3·4702
20	314 16	1·90400	2·14209	2·38000	2·61800	2·856	3·3322	3·808	4·2841
24	452·39	2·74175	3·08461	3·42719	3·76991	4·1125	4·7983	5·3623	6·1692

* Factor = A T + 33,000.

The following is the rule:—$10^2 \times 2 \times \cdot 7854 \times 2\cdot 5 \times 2 \times 35 \times 40 \div 33{,}000 = 33\cdot 3$-horse-power. The power of the engine will not be affected by the gearing of the engine;

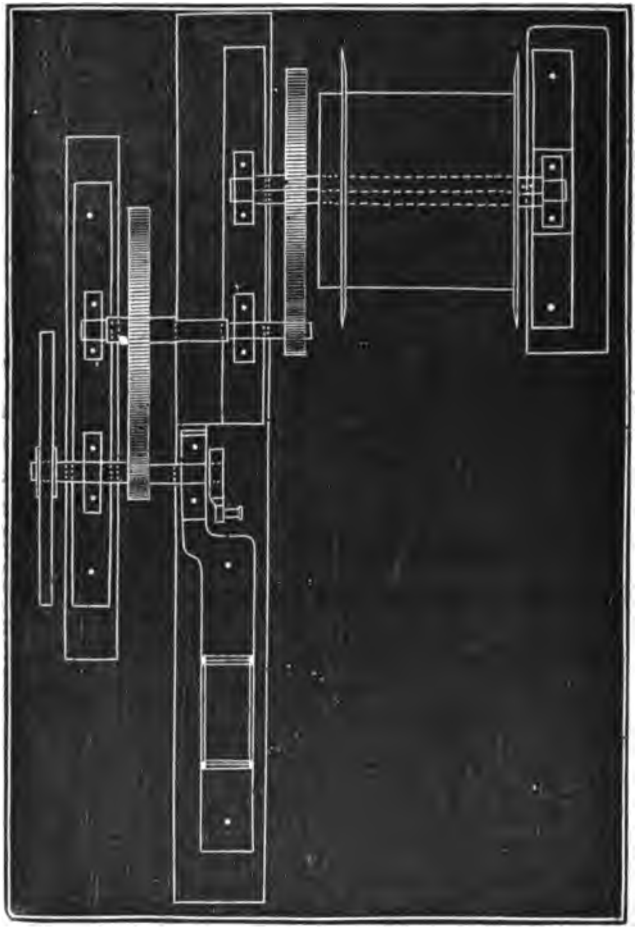


Fig. 223.

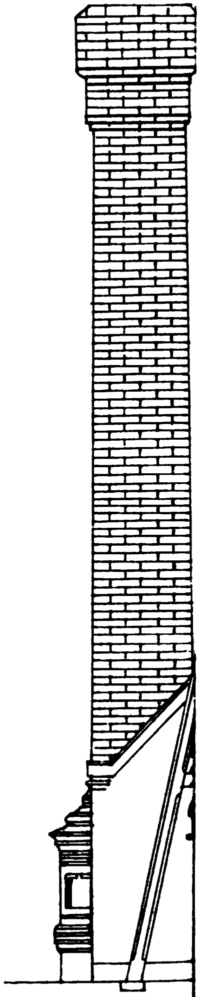
and the speed of the drum (see fig. 223) will be in the ratio of $\frac{15 \times 20}{70 \times 80} = \frac{3}{56}$, so that the crank shaft will make 56 revolutions while the drum shaft is making 3 revolutions.

612. If the main engine shaft makes 60 revolutions per minute, and a wheel 6 ft. in diameter keyed upon it is driving a belt running on another wheel 3 ft. in diameter, and it is desired to put in another shaft which shall revolve 400 times per minute, give the diameter of an additional pulley on the shaft of the second wheel, and also the diameter of that on the new shaft.

The second wheel being half the diameter of the driving-wheel, will necessarily revolve twice as often, or 120 times per minute. This is a belt speed of 140 ft. per minute. Supposing that the speed of the belt is to be increased to 1,800 ft. per minute, the diameter of the first of the new pulleys will be:—$\frac{1{,}800}{120 \times 3{\cdot}1416} = 5$ ft. nearly—that is, the belt speed divided by the number of revolutions of the driving shaft will give the circumference of the pulley, and the circumference divided by 3·1416 = the diameter. When the belt speed is 18,000 ft., and the number of revolutions of the driving pulley is 400, the circumference of the driving pulley will be 1,800 ÷ 400 = 4·5 ft., and the diameter = 4·5 ÷ 3·1416 = 1·43 ft., or 1 ft. 6 in. diameter nearly; or, with a driving pulley 5 ft. in diameter, making 120 revolutions, if the driver is required to make 400 revolutions, then as 400 : 120 :: 5 : 1·5 ft. = diameter of driven pulley.

613. Can you give a good sketch of pit-head gearing, engine-house and erection of chimney stack ?

Yes. Fig. 224 gives a side elevation of pit-head gearing, and shows in detail the pit frame pulley, guide-rods and frame. Fig. 225 shows an end elevation, together with the front of the engine-house and stack. The designs, which are by the late Mr. William North, of Dudley, have been adopted at the Aldridge and other collieries. In general appearance the whole plant is pleasing, but utility has not in any way been sacrificed.



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It has been well said that a thing is beautiful in proportion as it is adapted to the purpose for which it is intended, and even in such prosaic matters as colliery erections this principle applies and might be oftener remembered with advantage. The chimney stack is especially well designed, being a round one, with a really elegant base, and a substantial and well-constructed cap. The stack, it will be observed, is almost as wide at the top as the bottom. This is as it should be. How little did the early stack-builders understand rules which should govern their work. The ordinary type, almost of pyramid shape—excessively wide at the base, and ridiculously narrow at the top—violates the very fundamental law that the capacity of an airway is the measure of its smallest area.

614. In building a chimney or engine-stack, what principles should be observed?

The higher the stack the more draught. Just as in a shaft, the deeper the upcast the more powerful the furnace, and the greater the quantity of air. With some engine-stacks only a certain quantity of fuel per hour can be burned—they are not high enough. On the other hand, if the engine-stack is too high, too much fuel will be burned, but with a damper at back end of boilers the draught can be regulated, so that just the desired quantity of fuel is consumed. The following is a good rule:—Measure the area of all the firegrates, then calculate how many pounds of fuel should be burnt on them. Multiply both these by themselves, and the first one again by 4; then divide into the last one. For instance, suppose the firegrates are 140 square feet, and the fuel needed per hour 2,100 lb.:—

Then, $\frac{2{,}100 \times 2{,}100}{140 \times 140 \times 4} = 56{\cdot}25$, or $56\frac{1}{4}$ ft., height of chimney or engine-stack.

615. Give a short description, with sketch, of a good lubricator for steam engines?

With the old type of lubricators a regular supply of oil could not be ensured, and a good one regulating the

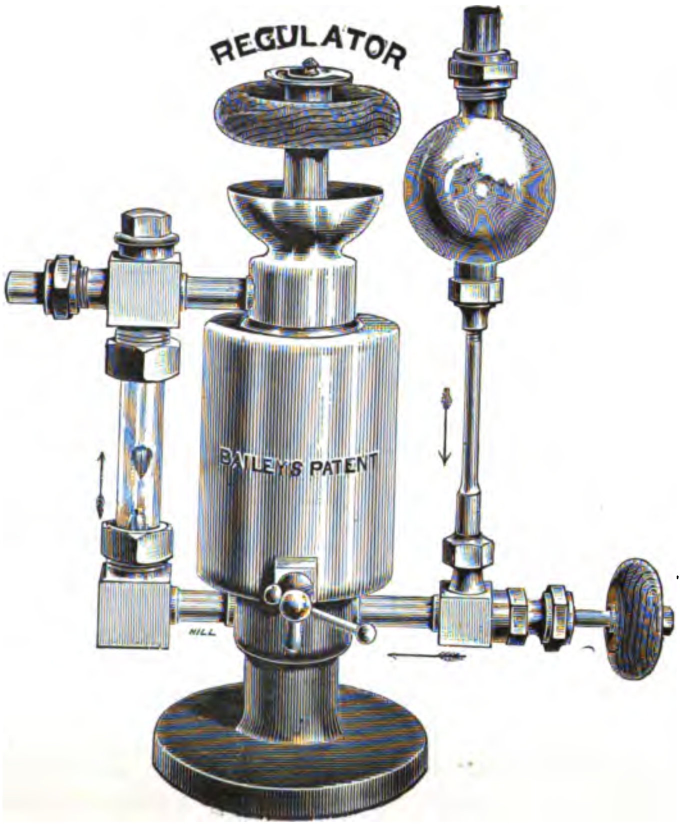


Fig. 226.

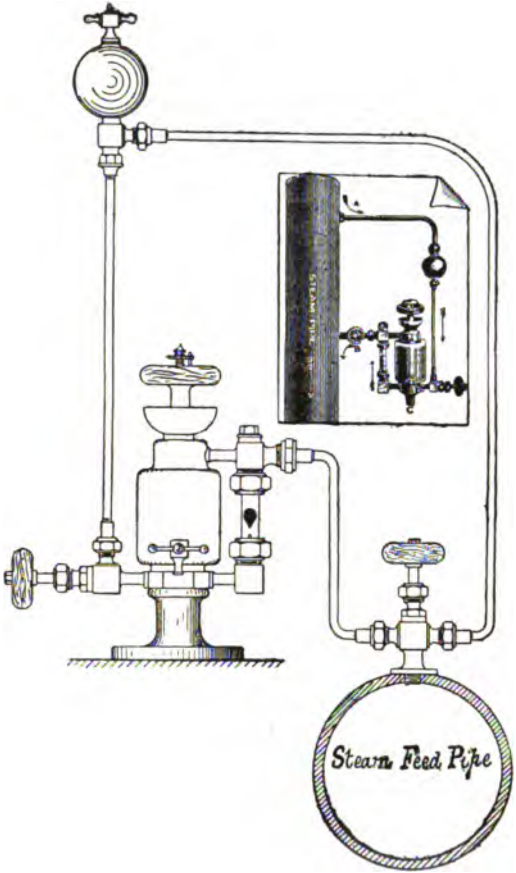
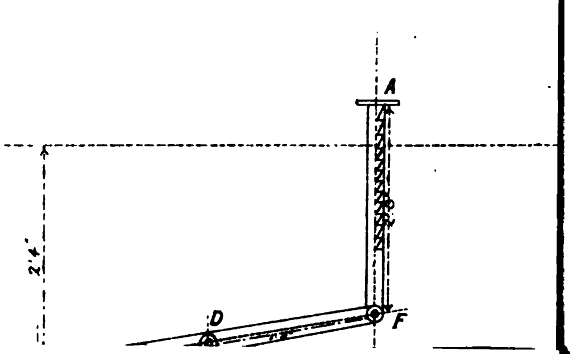


Fig. 227.


A
2'4"
D
F

admission of oil in judicious quantities as required is very desirable. Figs. 226 and 227 are sketches of a sight-feed lubricator, patented by W. H. Bailey and Co., of Salford, Manchester. The lubricator may be fixed on the steam-pipe on the boiler side of the throttle-valve, thus making the steam itself the vehicle for conveying the oil to the internal working parts of the engine. Users of these lubricators say they save 70 per cent. of oil.

616. Can the power of a foot-brake be increased without changing the position of the working parts, and still keeping the step-ratchet at the foot of the engine-tenter?

Yes. An easy and effective method is shown in figs, 228, 229, 230 and 231. It will be seen at a glance that to increase the length of the lever would be impracticable, as this would place the step-ratchet, A, beyond the control of the engine-tenter, but by lengthening the lever from B to C, then cranking it to D and attaching a new arm, E F, to the end of which the step-ratchet, A, is fixed, the lever is again brought into the position it occupied at first, but with the added power afforded by the extra length of leverage, the ratchet being kept in place by a weight appended at the end of the arm, E. The fulcrum is at the top of the baulk, G. The first brake of this kind was manufactured by Messrs. Walker Brothers, of Wigan, and laid down under the author's supervision. Figs. 229, 230 and 231 show the whole construction, with details.

617. Give a short description, with sketch, of a good screw-brake for a self-acting incline dipping 1 in 5, working with an endless rope, the load to consist of 20 full tubs and 20 empty ones.

Fig. 232 supplies what is necessary in such a case, where something more powerful and reliable than an ordinary lever brake and strap are required. The construction is simple and substantial, and there is no liability to get out of order with anything like ordinary care. The strap is a flat wrought iron one working on a cast iron segment, either attached to a drum or brake wheel, according as circumstances require, and is in contact with the periphery almost all round. The power is applied by means of a screw and a short lever arm, something similar to a railway brake; it is gradual in its pressure and firm in its grip. I consider it as safe and serviceable a brake for the purpose as I have met with.

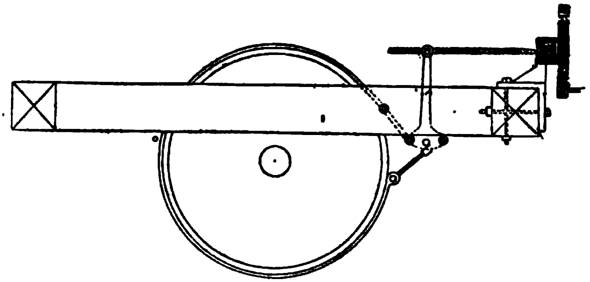


Fig. 232.

618. What weight will a pair of engines raise with 22 in. cylinders, 4½ ft. stroke and 8 ft. drum on the first motion, and 40 lb. steam pressure?

The total pressure will be $22^2 \times \cdot7854 \times 2 \times 40 =$ 30,410 lb., and making allowance for relative resistance of drum and stroke of engine, which are as 16 to 9, the weight raised would be $30{,}410 \times \frac{9}{16} \times \frac{7}{10} = 5\cdot34$ tons.

619. If you had a winding engine on the second motion, where would you put the brake?

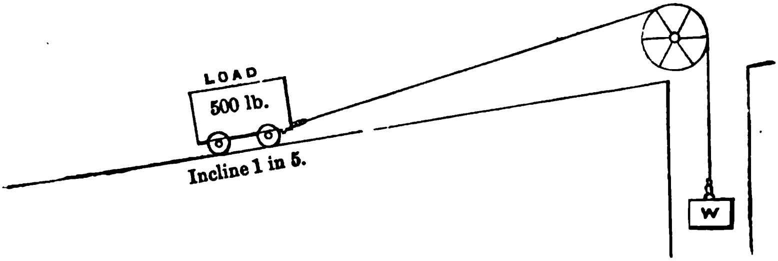
On the drum.

620. With an incline plane lying at an angle of 1 in 12, or the vertical rise of which is 6 ft. in every 72 ft. in length, what power or equivalent weight will support a load of 350 lb., friction *nil*?

The power required would be as follows:—$\frac{350}{12} =$ 29·16 lb.; or similar results are found by another rule, thus:—$\frac{350}{72} \times 6 = 29\cdot16$ lb., power same as before.

621. With an incline plane lying at an angle of 1 in 5, or a vertical rise of 20 ft. in every 100 in length, what power or equivalent weight will be required to balance a load of 500 lb., reckoning friction at one-82nd of the load?

The power required would be $\frac{500}{5} = 100$ lb.; again, the same results are found thus:—$\frac{500}{100} \times 20 = 100$ lb., power required to balance the load. If the friction is one-82nd of the load, the power required will be $F = \frac{500}{82} = 6$; then $100 - 6 = 94$ lb. This answer is illustrated in fig. 233.



W = 94 lb.

Fig. 233.

622. If it takes a power of 230 lb. at a velocity of 75 ft. per minute to move weights up an incline plane with a vertical rise of 12 ft. in every 163 ft. in length, the lowest velocity of the weight to be 8 ft. per minute, find the greatest weight this power is equal to.

The greatest weight this power is equal to is $230 \times 75 \times 163$ length $= \frac{2{,}811{,}750}{12 \times 8} = 29{,}288$ lb., or $13\frac{1}{4}$ tons.

623. If it takes a power of 400 lb., at a velocity of 60 ft. per minute, to move weights up an incline plane with a vertical rise of 40 ft. in every 200 ft. in length, the lowest velocity of the weight to be 10 ft. per minute, find the greatest weight this power will be equal to.

The greatest weight this power is equal to is $400 \times 60 \times 200$ length $= \frac{4,800,000}{40 \times 10} = 12,000$ lb., or nearly 5 tons.

624. Find the breaking strain of the teeth of a cog-wheel, estimating the velocity of the wheel 2·27 ft. per second, when each tooth measures as follows:—Breadth of tooth 6·75 in., thickness 2 in., length 3 in.

The rule to find the strength in horse-power of a tooth in a cog-wheel is: Multiply the breadth of the tooth by the square of its thickness, and divide the product by the length; the quantity will be the strength in horse-power, and again multiplied by the velocity. Example: $\frac{6{\cdot}75 + 2^2}{3}$ =9-horse power, then $9 \times 2{\cdot}27 = 20{\cdot}43$-horse power with a velocity of 2·27.

$$\text{Formula: } \frac{t^2 \times b}{L} = \text{strength.}$$

625. Find the horse-power of a steam engine, cylinder 35 in. diameter, length of stroke 6 ft., number of strokes per minute 20, effective pressure of steam 20 lb.; also give the dimensions of the teeth of a spur wheel keyed on the crank shaft of the above engine which will drive another wheel to work a pair of lifts, the velocity of the spur wheel at pitch circle to be $5\frac{1}{2}$ ft. per second.

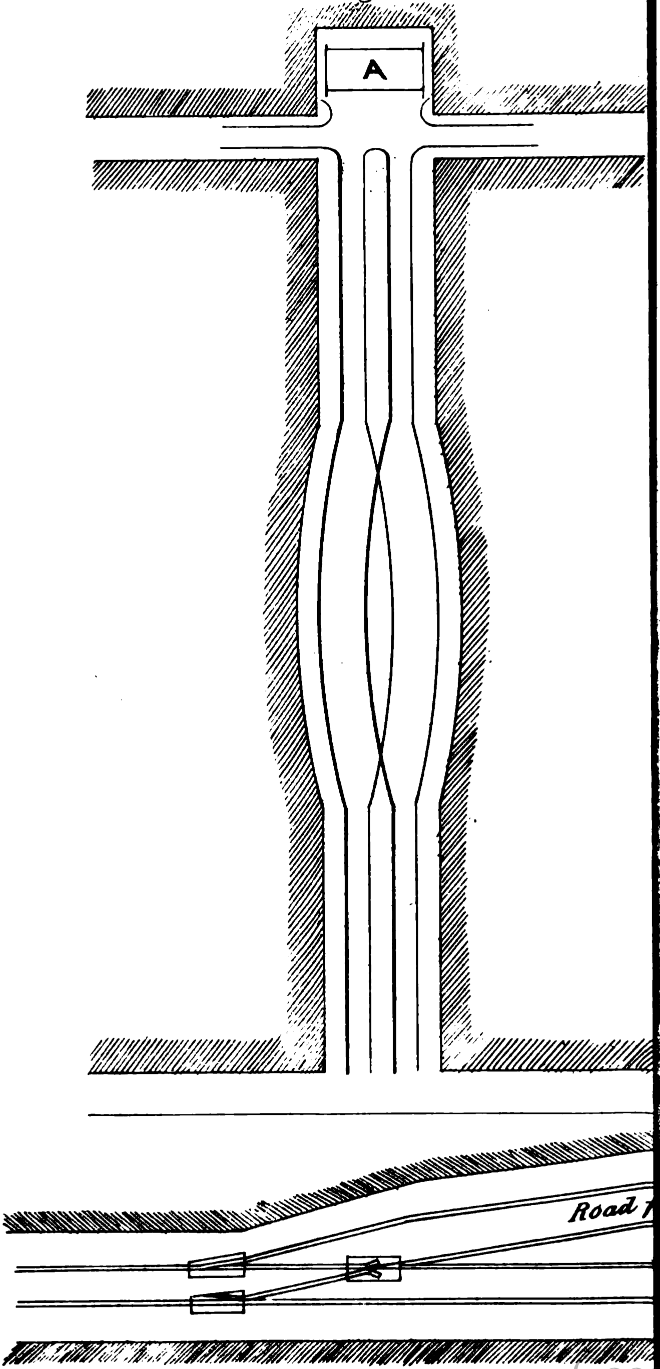
The horse-power of a steam engine is as follows:—Let D denote diameter of cylinder; L, length of stroke in feet; N, number of strokes per minute; and P, effective pressure of steam, then—

$$\frac{D^2 \times {\cdot}7854 \times L \times N \times P}{33,000} = \text{H.P.; thus—}$$

$$\frac{35^2 \times {\cdot}7854 \times 6 \times 20 \times 20\text{ lb.}}{33,000} = 69{\cdot}98 \text{ H.P., or nearly 70-}$$

horse power; so the teeth of a spur wheel to suit the above engine will be: Breadth of tooth, 8 in.; thickness, 2 in.; length, $2\frac{1}{2}$ in., or $t = 2^2$, $b = 8$, $L = 2\frac{1}{2}$; or thus $\frac{2^2 \times 8}{2{\cdot}5} = 12{\cdot}8 \times 5{\cdot}5$ velocity of pitch circle $= 70{\cdot}40$ H.P.

Fig. 235.



626. Ninety tons of coal per hour are to be drawn up an engine plane 800 yards long and dipping 1 in 8; what must be the horse-power of the engine, allowing one-half for empty tubs, rope, friction, &c.?

Rule: 800 × 3 = 2,400 ft. ÷ 8 = 300 vertical height in feet, and 90 ÷ 60 = 1·5 tons per minute, and 1·5 × 2,240 = 3,360 lb. per minute, and 3,360 × 300 = 1,008,000 total foot-pounds, and 1,008,000 ÷ 33,000 = 30·54-horse power, and allowing one-half for empty tubs, rope, friction, &c., the horse-power required would be 504,000 + 1,008,000 = 1,512,000 ÷ 33,000 = 45·81-horse-power.

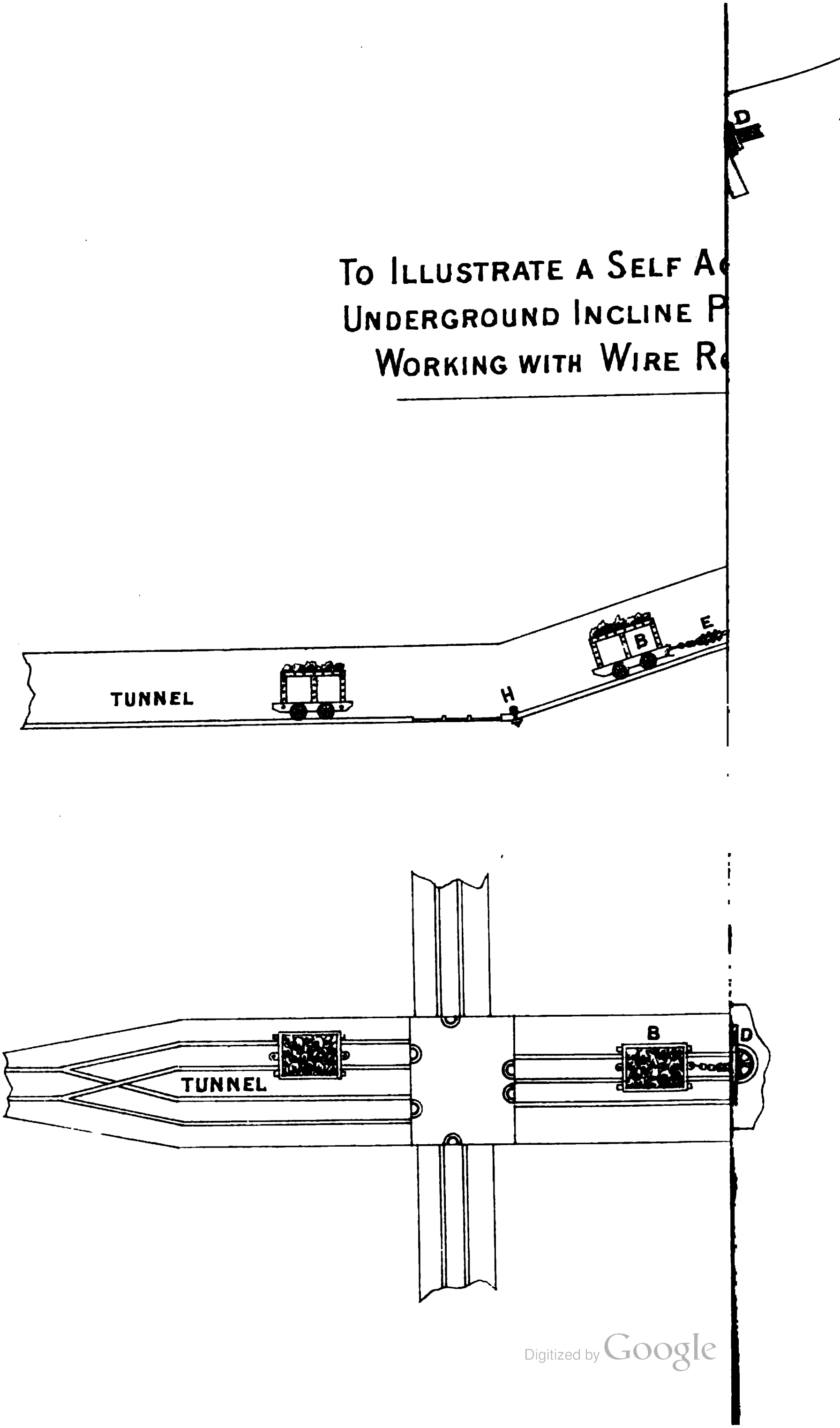
627. With a self-acting incline or jig brow 500 yards long dipping 1 in 12, down which it is wanted to run 300 tons of coal per day, how would you perform the work?

Supposing the day to consist of eight hours, and each tub to contain 10 cwt. of coal, I would perform the work as follows:—Run 12 tubs in each journey = 6 tons, and 300 ÷ 6 = 50 journeys per day. Example: $\frac{8 \times 60}{50} =$ 9½ minutes per journey for jigging and changing at top and bottom.

628. How should the jig-bottom be laid out where there is a self-acting incline plane or jig-brow dipping 1 in 3, and it is desired to jig four tubs each journey?

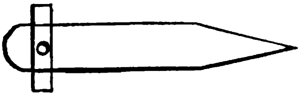
I would lay out the jig bottom as shown in fig. 234. It will be seen that in the sketch there are no landing or turn plates at the bottom of jig, as is usually the custom when the jigs are of as high a gradient as 1 in 3. The following short description will make the sketch clear:—The points A are self-acting—that is, they work by fixed springs; the points B are loose points, put in position so that the empty gang goes up by the loaded gang which has last come down—that is, suppose the last gang of loaded wagons to have come down on the set of tram rails C, the next empty gang will go up on the same set of tram rails, and on the set of tram rails D the loaded gang would come down and put the points B in position for the next empty journey. The points A being self-acting, are always in position to turn the loaded gangs on the set of tram rails E; for the direction of pit-eye the empty gangs are always put on from the set of tram rails F. H is a pile of timber fixed between roof and floor for support in the centre of jig bottom and roadways. The author has laid down jig bottoms on this principle with the inclination up to 18 in. per yard, and they have always worked satisfactorily, 150 tons being run down per day, requiring only one boy to unhook the rope from the loaded gang and attach it to the empty one, as the wagons pass round the curves on tram rails at E and F without any attention, providing the rails are well and substantially laid down.

The author is indebted to Mr. Miles Settle for the following description of a double rail jig-brow, and also for the sketch and description of a three-rail dip which follows. Fig. 235 illustrates a jig which appears simple in construction, but it is a very useful form, more especially where the roof is bad. It is only 5 ft. wide, except at the centre, and worked with double rails, 2 ft. gauge; each rail is fixed 1 ft. apart, and allows 6 in. on each side of a tub 3 ft. wide. The object is to keep the rope wrapping on the drum, A, uniformly, putting no friction on the rope with the descending wagon. The road must be made sufficiently wide at the meetings to allow the tubs to pass. On looking at the plan it may seem impossible for the wagons to pass, but trace the heavy line marked for the one side, and the lighter black line for the other, and it will be plainly seen that sufficient room is allowed. Fig. 236 shows a road known as a three-railed jig with crossing in the centre to allow the tubs to pass, the tubs always landing on the single road at the bottom. It could be worked with a single road on the top, but three rails are preferable on account of the rope wrapping on the drum more uniformly. A switch must be fixed at point A, an



To Illustrate a Self A
Underground Incline P
Working with Wire R

ordinary piece of wood 8 ft. long, 4 in. × 2½ in., thus spiked down can be worked automatically, the full loads descending always putting the rails in position for the next journey of empty wagons to ascend the same line.



629. Which rail on a curve should be the higher?

A tub or gang of tubs or railway wagons passing round curves always has a tendency to run in a straight line, to counteract which the outer rail is raised somewhat, thus offering a better resistance to the flange of the outside wheel, and the wagons, as it were, are placed on an inclined plane, and by their own weight slip towards the centre of the curve; the height of the outer rail is regulated by the angle of the curve and by the velocity of the tubs passing round it.

630. How would you work an advancing balance-brow, the dip being 1 in 5, and to be worked with wire rope?

Figs. 237, 238 and 239 give section and plan of a balance-brow worked with a wire rope. A is the balance-box, generally partly loaded with rock or other material to counterbalance the loaded tub, B, while descending, and the empty tub when ascending. The balance-box is attached to the rope by means of screw glands, C, and as the brow advances the balancing wheel, D, is moved forward and the rope lengthened, the gland, C, being slackened and spare rope to the required length being taken out of the balance-box. By this system a balance-brow could be driven any distance without splicing the rope, sufficient length of spare rope being coiled in the balance-box as shown. The system is also well suited to cases where loaded and empty tubs require to be put on and taken off at intermediate levels upbrow. To illustrate this arrangement we will suppose there are one or two or more levels in the brow where loaded tubs are to be put on and empty ones taken off. For this a strong sleeper having a projecting iron jaw screwed in the middle, termed a "jaw sleeper" (fig. 239), will be required. When an empy tub comes up the brow to a level where it is to be taken off, the end of the rope, E, is pressed down with the foot into the jaw, F; a small pin, G, is then passed through two holes in the jaw over the rope to hold it; the empty tub is then taken off, the rope and the balance-box being firmly held by the jaw until the loaded tub is put on, when the pin, G, is drawn out, the rope liberated, the load balanced, and so on. To facilitate the putting on and taking off of loaded and empty tubs at each level there is an iron landing or turning plate slotted to the gauge of the tram road. When the loaded tub has reached the bottom, the end of the rope is pressed in another jaw, H, and the load taken off, the rope and balance-box being securely held until another empty tub is put on, then balanced up and so on. The foregoing is a simple and effective system where the inclination is not more than 1 in 5.

Mr. Miles Settle has kindly placed at the disposal of the author the following sketch and remarks upon the balance dip or jig as worked in the steep mines of North Staffordshire:—Balance dips or jigs are very useful where there are several landings or levels to put coals on. On one side of the jig is a "dummy" load or balance wagon, B, (figs. 240 and 241) about 2 ft. high and 5 ft. long, which is loaded with any *débris* or old iron sufficiently to pull the empty tub up the dip, and the full load will pull the "dummy" up again. Balance dips can be worked most beneficially at an angle of 10 degs. or 15 degs. They may, indeed, be worked at any angle, but at more than 35 degs. a cage must be put in to bring the coals down in an horizontal position, thus increasing the percentage of round coals and with less wear and tear on the pit tubs. Every balance wagon should have a self-acting drag. It must be above the axle of the front wheels and below the axle of the back wheels, with prongs like a hay-fork, the front being turned up, so that

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when the rope is attached the drag is kept from the floor. Should the rope break, the drag stops the descent of the balance wagon. The balance wagon must be placed on that side where the smallest quantity of coal is to come from. Coals can be put on at either side by raising the road over the balance wagon side; 1, 2, 3 and 4 are levels, and slotted plates must be put in the jig opposite each level.

631. Give a short description, with sketch, of a good coupling for tubs.

Fig. 242 is a sketch of a coupling; the special feature over the old type is that two small links, A, are fixed in the hooks of the coupling; the links are always in an inclined position, and act as a safety link, preventing unhooking should the coupling get slack in any part of the run.

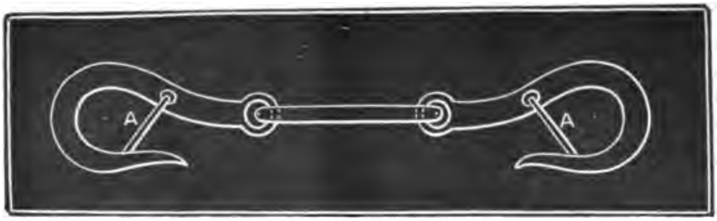


Fig. 242.

632. What may cause failure in a self-acting plane?

The inclination at the bottom may be steeper than at the top; or, in other words, the plane may be too flat at the top and too steep at the bottom. To make it work, the top part of the plane will require raising or the bottom part taking up, or the rope or chain may be too heavy, or a sufficient number of tubs may not be put on at a time.

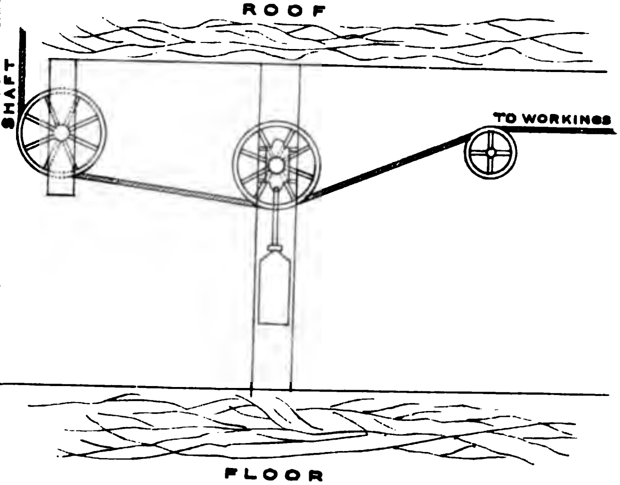
633. Which system of underground haulage do you consider generally the best—the tail rope, endless rope, or the endless chain?

As a rule, the endless rope system is the best. With the tail rope, a large number of stations are required to work branch roads, more rope is required, the wear and tear on the rope is greater, there is greater liability to accident and damage through the quick speed at which the tail rope is run, greater power is required, with consequent increased consumption of fuel, owing to the friction of the rope on the rollers and the brake on the drums, occasioned by loss of the compensatory action of the gravity of the tubs on undulating and inclined roadways. The endless chain is objectionable on account of its great weight and for other reasons; for instance, in one mile length of roadway an endless wire rope 2½ in. circumference and 7½ lb. per fathom will weigh about 5 tons 18 cwt., whereas a similar length of chain ⅞ in. diameter, and 29 lb. per fathom will weigh about 22 tons 15 cwt., and the latter will require a man or boy to attend to the tubs while working round the curves. The endless rope system can be applied under almost any conditions, the crookedness of the roadway, the irregularity of the gradients, numerous branches and stations—forming no obstacles to its effective working.

634. Give a short description, with sketches, of a system of endless rope haulage with which you have personal acquaintance.

Figs. 243, 244, 245 and 246, illustrate a system designed by the author at the Aldridge Collieries, and it has proved both satisfactory and economical. Starting with the motive power, the engine, which was previously fixed on the surface and ordinarily used to work a saw-mill, has a 12 in. cylinder, and for the purpose of hauling was geared 1 to 8. The rope is driven by a plain C wheel at A, 6 ft. diameter, thrown in and out of gear by a clutch. There are two and a-half laps of rope, which give sufficient grip and avoid the necessity of a costly friction wheel. I would here observe that experience has fully justified this substitution, for while there is no "slack" and no slipping of the rope in the ordinary course of work, in case of any serious obstruction on the engine plane, the rope does slip, and by so doing not only gives instant warning to the

Fig. 246.



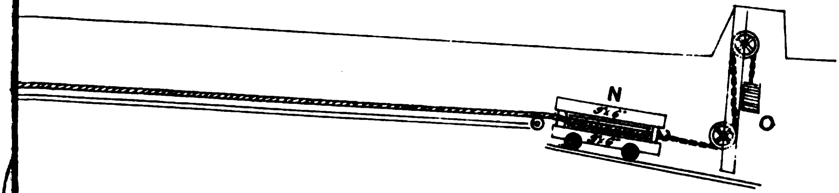
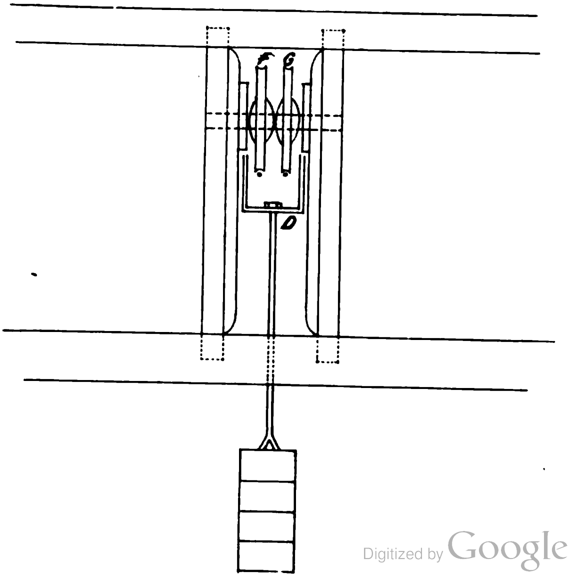
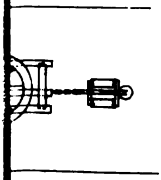


Fig. 245





engine-tenter, but by yielding prevents great damage to the machinery, hauling rope, and not infrequently to the roadway rolling stock. At B (section) is a sketch of the arrangement, of the ropes, pulleys, &c., at the pit head, and section C and ground plan the same at the pit-bottom—a depth of about 500 yards. Figs. 245 and 246 are sketches of the arrangements for balancing or tightening the main rope from surface. Fig. 245 shows the main balancing arrangement which acts both on the ingoing and outgoing rope by means of a cross-head, D, attached to the two sliding pedestals in which the pulleys, F and G, work, a weight of about 8 cwt. being attached beneath. Fig. 246 shows an additional balance applied to the outgoing rope only, by a single pulley working in sliding pedestals which move up and down four small iron conductors (as a cage does), and by these appliances the rope is without difficulty kept tight. H shows the termination of the main rope, and a vertical shaft worked by the pulley I, which transmits the power to the second hauling rope along the engine plane off pulley J; there are two and a-half laps of rope round each of these, and by means of a clutch applied to the pulley J, the haulage can be thrown out of gear, and the main rope as well as the shaft H be utilised for pumping purposes. K shows a section of the engine plane, starting with the arrangement of pulley L and roller M, by means of which the rope is brought into the required position. N is a balance box of the author's design at the back end of the engine plane; it is fixed on wheels and works freely on rails. The effectiveness of the arrangement is increased by the fact that this balance-box works on a steep gradient specially excavated, and thereby adds its own weight, as well as the resistance gained, to the dead weights attached to the end of chain at point O. P shows working plan of the engine plane. The road, which is 900 yards in length, presented considerable difficulties on account of the varying gradients and numerous bends, one of them being at right angles. The gradient varied from 1 in 24 to 1 in 5, and one upthrow fault of 10 yards had to be negotiated, which completely reversed the gradient for a distance of 80 yards. To deal with this and the turns in the road, special rollers and pulleys were designed, sketches of which are shown in figs. 247 and 248, the latter showing a tub attached to the rope and passing round a pulley at one of the turns. An electric signal of a simple kind is fitted, and can be rung instantaneously at any point of the road by bringing the wires into contact. The average speed of the rope is 2½ miles per hour; it can be stopped in a distance of 6 ft.

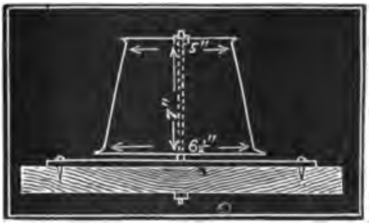


Fig. 247.

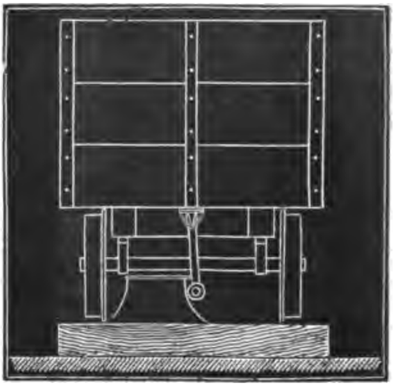


Fig. 248.

The system here described has proved very successful, a much larger tonnage than formerly being brought to the pit, and the quantity can be still further increased, if required, to at least 400 tons per day; previously twelve horses were employed to haul about 100 tons, owing to the steep incline almost all the way to the shaft. The difficulties which have been overcome at the Aldridge Collieries would go to prove the practicability of a system of endless rope haulage under most conditions.

635. Have you had any experience in adapting endless rope haulage gearing to pumping purposes?

Yes; in connection with the endless rope haulage described in last question, a connection was made for the purpose of pumping the water from the sump and forcing it up the shaft a distance of 50 yards vertical. The attachment was made in this manner. Referring to fig. 249, it will be noticed that the vertical shaft corresponds with shaft H on haulage plan (figs. 243 and 244). To the top of this a crank is attached, firmly keyed to the shaft and on the crank-pin is a revolving arm working loose; to the back end of the arm a short chain is fastened, which works over a pulley fixed a few yards away, and carries a balance weight, A, which counterbalances the rope that works the pump. To the fore end of the arm is attached the pump rope, which is carried along the roof over small pulleys 60 yards to the shaft and then down to the pump, which is fixed 40 yards below. The rope is fastened on to the end of the pump-rod, so that the lift is direct. The water is pumped from the sump, and forced, as before stated, about 50 yards vertical into a pound-room, from which it is liberated as necessity requires, and drawn in tanks to the surface. The cost of this arrangement was trifling, as an

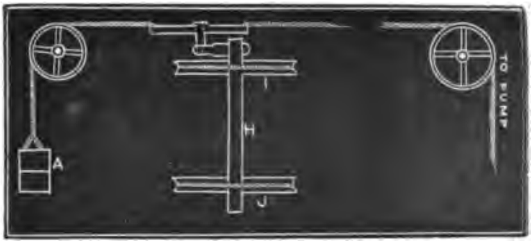


Fig. 249.

old winding rope was used, and all the working parts fitted up by the colliery workmen. This pump superseded one that had been working by steam; which, of course, interfered with the ventilation, the shaft in question being the downcast.

636. Which driving wheel or clip pulley do you consider a good one for endless rope haulage underground or at surface?

There are three kinds of driving wheels or clip pulleys generally in use—(1) the clip pulley; (2) the ordinary driving pulley, with the rope coiling two or three times round it; (3) a pair of grooved wheels, with the rope coiling partly round each of them, four to six times. The

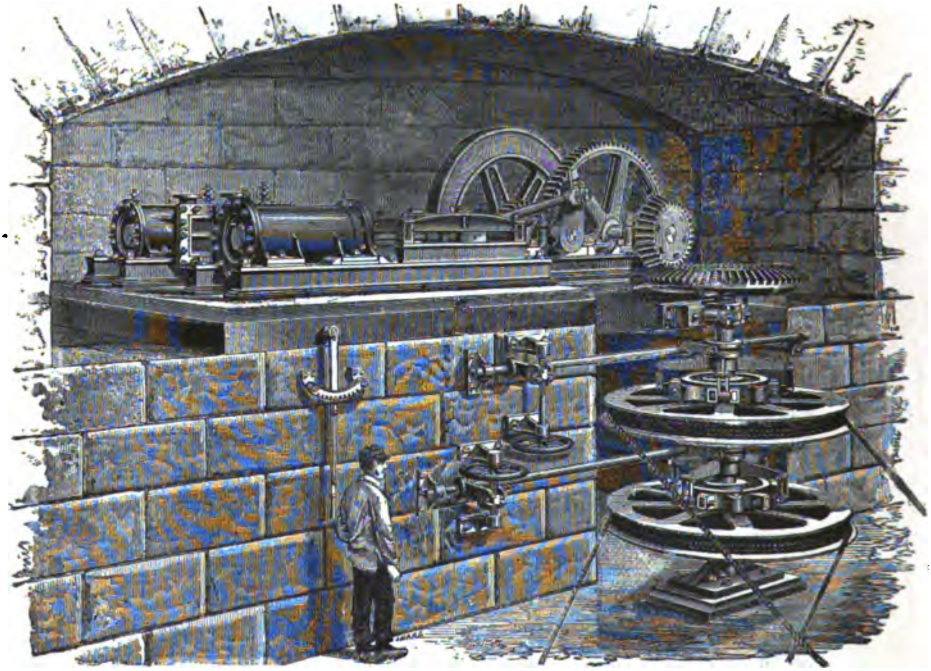


Fig. 250.

best driving wheel that has come under my notice is one manufactured by Messrs. Walker, Wigan, and is Fisher and Walkers' patent friction clutch, illustrated in figs. 250, 251, 252 and 253. These clutches have been at work for some time at the Linby and Clifton Collieries, near Nottingham, where the author has seen them, and can speak as to their efficiency. The chief features in the construction of the clutch are:—A cast iron disc is firmly keyed to the main shaft, *f* (figs. 252 and 253). Round the periphery of the disc, which is truly turned, there is a belt of steel, *g*, composed of three or more segments. The segments are held together by bolts, *k*, which have right and left-hand threaded screws formed at each end. The bolts can be made to turn, more or less, by the levers, *o*, operated by the cross, *p*, which is controlled by the weigh shaft, O, and the hand-wheel and screw shown on fig. 251. The pins, *e*, fixed in the wheel, *b*, connect the wheel with the belt at the projections, *n*. The movement of the

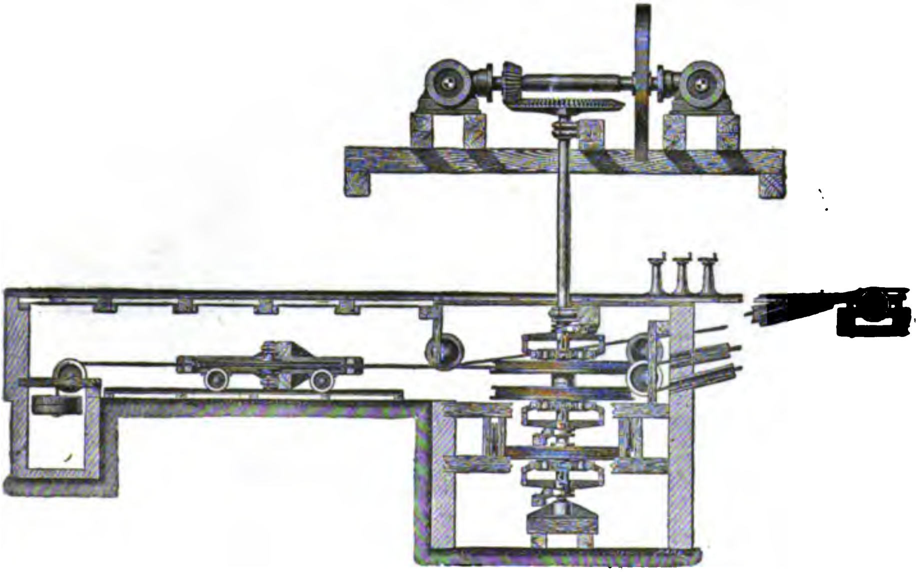


Fig. 251.

gripping belt, *g*, with the right and left-handed threaded screws is the chief thing to be noticed, and, in short, is the salient feature of the whole clutch. The action is by the gradual contraction or tightening of the belt (by means of the right and left-hand threaded screws) round the outer edge of the revolving disc. The motion of the disc and shaft is thus gradually given to the belt through the pins, *e, e, e, e,* to the wheels and other gearing required to be turned. In the event of any violent strain being thrown upon the latter, the two surfaces of the steel belt and disc slip one over the other, the slip being dependent upon the original degree of grip put on the clutch by the attendant. Any injury to the machinery is prevented by the slip of the gripping surfaces under violent shocks or strains. In fig. 250, three rope wheels are shown on the vertical shaft, round which the haulage ropes are coiled for the working of as many different roadways. To each of these wheels

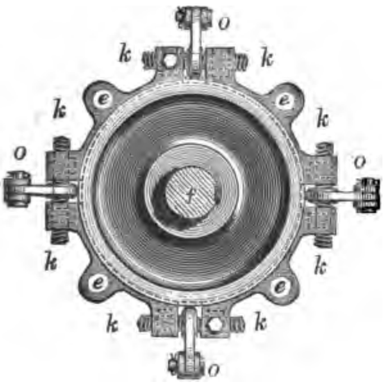


Fig. 252.

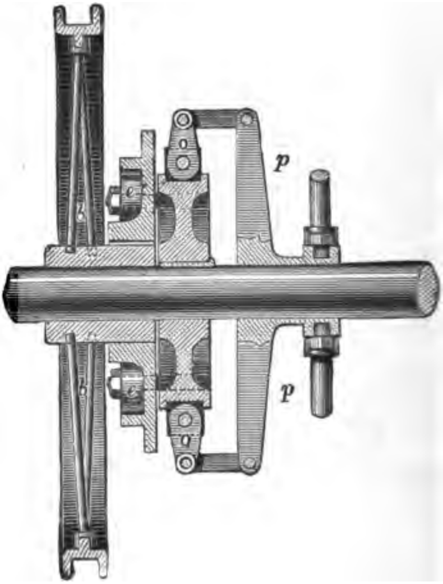


Fig. 253.

there is a patent friction clutch. These are controlled through the mechanism now described, by the hand-wheels on the top of the three columns; the same principle obtains in every application of the clutch, but it may be modified to suit every special circumstance. In order to obtain the necessary slip to avoid breakages from extraordinary strains, the grip of the clutch should be adjusted to do the required work only. If screwed too hard and fast, the purpose of the "friction clutch"—slipping when over-strained—is practically lost. The clutch described has advantages over other clutches; the friction pressure of the steel belt encircling the disc is uniform over the whole surface, as the grip is gradual, the steel band is in tension, while the disc is under a compressing strain. The clutch belt moves, opens and closes, expands and contracts concentrically to the disc, and its grip is uniform round the whole surface of the disc.

637. Give a sketch of a good clip for attaching tubs to the rope.

Figs. 254 and 255 are sketches of a clip invented by Mr. Fisher, of the Clifton Colliery, Nottingham, and is a generally approved one. Another clip which may be applied in any system of haulage is the "Smallman" patent clip, fig. 256. This clip consists of two side-plates, held together by a central bolt, and attached to the rope and detached therefrom by means of a suitably-shaped lever. The extremity of the short arm of the latter is enlarged and slides along the wedge-shaped recesses formed in the side-plates. By these means, an exceedingly powerful clip, capable of being instantly attached and detached, is produced. When adjustment is once affected, it is rarely requisite to interfere with the central screw, no matter what the load or gradient may be. The coupling is of the ordinary construction. The following amongst other advantages are claimed:—(1.) It is exceedingly simple, the parts being strong and few in number. (2.) By means of the central screw it may be easily adjusted, either to fit any particular rope or to compensate for wear. (3.) It is very economical in use, inasmuch as wear may not only be taken up by the central screw, but the longitudinal grooves formed in the side-plates for the reception of the rope are provided with shear steel liners, the latter being readily replaced when requisite. (4.) It is instantly attached or detached, and no particular skill is requisite in carrying out either operation. (5.) It will hold equally well either uphill or downhill; that is, it will either pull the load or hold it back. (6.) It possesses enormous holding power, and is now working with every satisfaction on a gradient of 1 in 2. (7.) It does not damage the rope, inasmuch as it grips the same for a length of five inches, the injurious "kink" involved

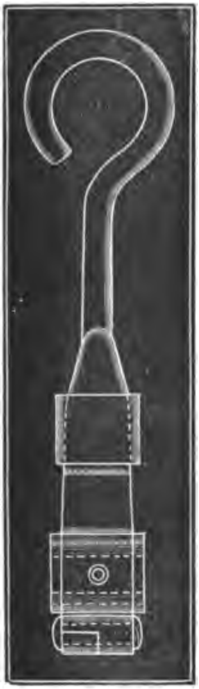


Fig. 254.

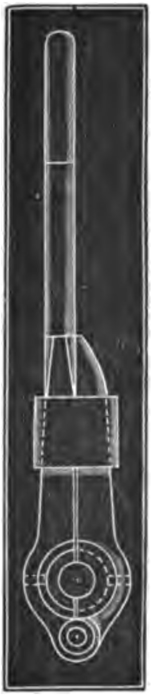


Fig. 255.

in using certain other clips being thus avoided. (8.) It is self-supporting, and passes freely round curves. (9.) It may have any form of coupling fitted to it, either "pivoted" or "rigid," to suit individual requirements. (10.) It does not jar loose, even when the working parts are, as they should be, well lubricated. At the Haunchwood Colliery the author inspected the clip in action on an incline of about 1,100 yards long, with a gradient varying from 1 in 6 to 1 in 3, and with a very sharp curve in it, 500 tons daily being hauled along this incline. From what the author saw of the clip at work, he considers it by far the simplest and best yet introduced. The author has had the clip at work on roads with very sharp curves, and in which the inclination is sometimes upwards and sometimes downwards, and it gives great satisfaction.

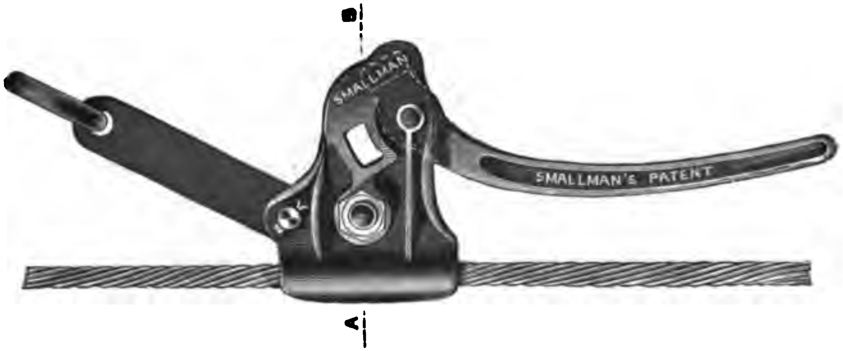
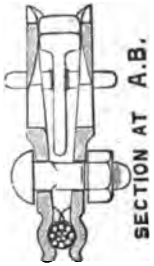


Fig. 256.



638. In putting down haulage plant for hauling coals in the underground works, would you fix your engine on the surface or in the underground workings?

I should be guided by circumstances; if practicable, it is always better to fix the engine underground, and as near to the haulage plane as convenient, so that the engineman has a sight of the haulage operations, and is not wholly dependent on the signals. Haulage engines fixed on surface are objectionable, on account of the extra length of rope required to work them, besides the great wear and tear on the rope from its having to pass round pulleys at the top and bottom of the pit; this is the case more especially when the tail rope or endless rope system is adopted, double lengths of rope being required in the shaft. For example, a shaft 500 yards deep would require 1,000 yards of dead rope in shaft alone. There are, however, cases where it is advantageous to have the engines fixed at surface; there may be an engine already fixed there which can be utilised, or it may be that the character of the roof, &c., of the underground works would render the making and maintenance of an engine-house too costly.

639. If in putting down haulage plant it is decided to fix the haulage engine underground, should the boiler be underground also, or would you convey steam from the boilers at surface down the shaft in pipes, or would you use compressed air?

Under almost all circumstances steam boilers fixed underground are objectionable, owing to the risk of fire to the surrounding strata, and the great expense incurred in making and maintaining the boiler-house, &c. To convey steam from surface to the haulage engines by pipes is also objectionable, especially if the shaft is of great depth and the engines far from the pit bottom, as there would be great loss of power, owing to condensation. Moreover, the heat and exhaust steam are very objectionable, and there is frequent inconvenience through the joints of the steam pipes blowing out, due to the expansion and contraction in pipes. Under ordinary circumstances I would drive the haulage engines with compressed air. Its advantages over steam are very great, and unlike steam, having performed its work it cools the air of the mine instead of heating it. The author's experience of compressed air machinery, extending over many years, and with engines by several makers, leads him to the conclusion that pressures of, say, 40 or 50 lb. to the square inch are the most economical. With great pressures there is loss of power by radiation of heat from the pipes conveying the air, and more danger of ice being formed in the exhaust ports of the cylinders. In the earlier engines it was common to actuate the air cylinders on the second motion, and not direct from the steam piston gearing; this, however, the author considers a mistake, both as regards efficiency and economy.

The air-compressing engines about to be described were erected by the author at a colliery recently under his charge and were manufactured by Messrs. Walker Brothers, Pagefield Ironworks, Wigan. They consist of an ordinary pair of horizontal engines with the air cylinders fixed immediately behind and in a line with the steam cylinders. The valves of air cylinders are a common source of trouble, but Messrs. Walkers' patent valves have proved a decided success, and to them much of the efficiency of the engines is to be attributed. In direct-acting engines of this class it has been urged that steadiness in working can only be gained by the use of very heavy fly-wheels, but as a matter of fact the irregularity is often due to wrongly-constructed valves. In the engines referred to, the fly-wheel is of moderate weight, about 5 tons, yet a piston speed of 600 ft. per minute has frequently been attained with cylinders 25 in. diameter by 4 ft. 6 in. stroke. At this high velocity the valves of the air cylinder work smoothly and with little noise; any tendency to clatter can be checked immediately while the engines are running. For the inlet valves india-rubber discs were originally fixed to the cylinder covers, but the valves now in use are of metal. India-rubber at a high velocity of piston was found to grow sticky and give trouble, and sometimes to be dissolving by the heat and oil of the cylinders. The steam cylinders and the air compressors are fitted with Ramsbottom pistons. The intake air is admitted through a rectangular valve fitted in the covers at the end of the cylinders. The discharge of air takes place from the upper part, through rectangular valves, the compressed air being delivered through metal pipes to the reservoir or receiver, which was a plain cylindrical boiler 30 ft. long and 6 ft. diameter. The compressed air from both cylinders is collected into one line of metal pipes, which deliver into the reservoir, the line of pipes being carried between the two pillars of the engines, and immediately beneath the fly-wheel. A stop valve was also inserted at the top of each compressor, so that they could be isolated and the engines relieved from pressure in the intervals of working. Two stop valves are also placed in the steam pipes. By the arrangement of these valves one engine and compressor can work independently of the other, and in the event of accident to either, the whole of the workings need not be laid idle. The author found it advantageous to put another stop valve in the line of pipes which leads from the reservoir to the top of the pit. This valve is for the purpose of shutting off the pressure immediately, instead of emptying the reservoir, to guard against danger from the breakage of a pipe or engine underground. The receiver, besides serving as a reservoir of power to store up the compressed air, very materially affects the engines both above and below ground, by promoting regularity and smoothness of working. The author attaches great importance to this detail. Any small quantity of water accumulating in the receiver is easily run off by a cock fixed underneath. A small receiver was also placed to each underground engine, actuated by the compressed air, in order to keep the air as dry as possible inside the cylinder; a roomy steam pipe will usually do, but sometimes for the larger engines receivers of boiler plates are used.

640. Has electricity been practically applied to underground haulage?

Electricity is making rapid strides, and there is no doubt that it is the coming motor so far as mining is concerned. Although in its practical applications the science may be said to be yet in its infancy, Messrs. Immisch, of London, have succeeded in producing a modern form of motor, for working an electric locomotive for underground haulage (fig. 257), which has so far proved superior to most of its rivals. Mr. Immisch has departed from the ordinarily received ideas on the subject of motor construction. He does not admit that the best dynamo is necessarily the best motor; but while admitting fully the theory of reversibility, he says that an efficient dynamo must from the nature of things be an inefficient motor. The motor used for the above is a 6 in. Immisch motor. Its weight is about 350 lb., and it will give eight-brake horse-power at a speed of 1,400 revolutions per minute. The efficiency, as tested by a Prony brake or dynamometer, averages 85 per cent. between 4 and 8-horse power. The efficiency of these machines ranges from 70 per cent. in a 1-horse power motor to 90 per cent. in one of 20-horse power. Measured by what is technically called "torque," which is the effort exerted to cause rotation, they show a very large amount of power in proportion to their weight. Mr. Immisch's electrician informs the writer that a machine of the same size as is shown will lift and maintain as its normal torque a weight of 14 lb. at the end of a lever of 2 ft. This is equivalent to a torque of 176 lb. foot,

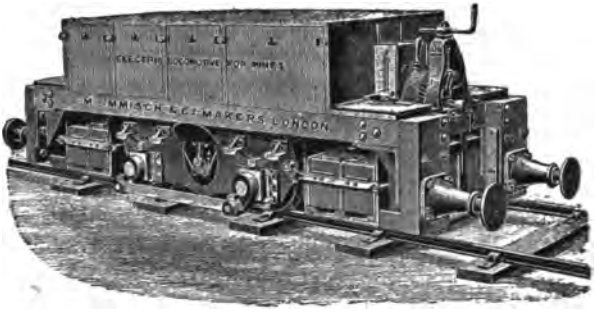


Fig 257.

and is equal to a pull of 112 lb. on the periphery of a pulley at the same diameter as the armature, viz., 6 in. At the same time the motor could momentarily exert a maximum torque of about five times that amount without damage. For stationary motors the conductors can readily be so protected that nothing short of a fall of the roof would cut them, and the sparking at commutators is rendered quite harmless by surrounding the commutators with wire gauze, practically running them inside the case of a safety lamp. The sparks, being at any rate very different from a continuous flame, give much less opportunity for any ignition of gas, even if unprotected.

641. Give a short description, with sketches, of an automatic knock-off link for detaching the gangs from the rope at the top of incline planes.

Figs. 258, 259 and 260 are sketches of automatic knock-off links, differing a little from each other in construction, but serving the same end. One explanation will be sufficient to explain the principle of all. Fig. 258 gives a side view of the knock-off link, first tub of the gang, and the arrangement for knocking off the link at the top of the ncline. When the gangs arrive at the top of the incline and most of the tubs are on the level, a horizontal bar of iron or timber, A, is fixed to the roof, or props of timber, as

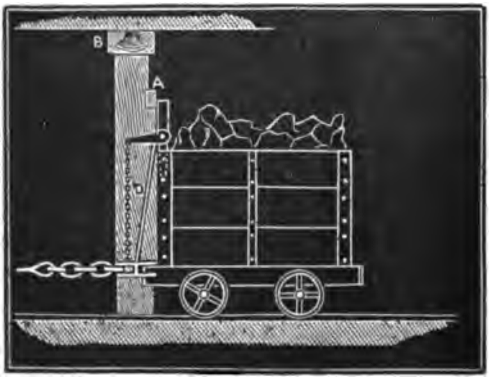


Fig. 258.

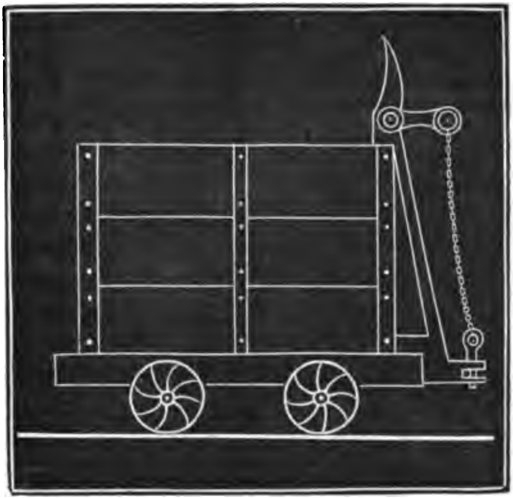


Fig 259.

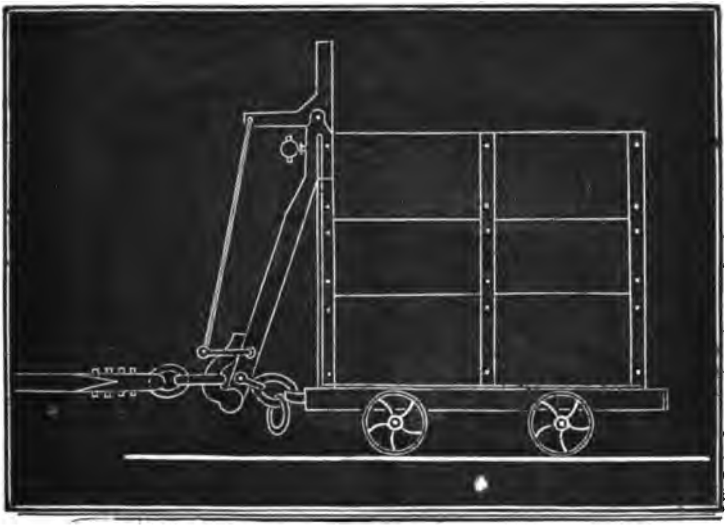


Fig. 260.

shown at B, just high enough for the loaded gang to pass under and allowing for the upright lever or arm to come in contact with it; when the upright lever comes in contact with the horizontal bar, it detaches the rope from the gang by the sudden withdrawal of a pin, which is connected to the lever by means of a small chain, D. The gang being thus liberated will pass on to its destination.

642. Give a short description, with sketch, of a knock-off link used in tail-rope haulage.

Fig. 261 is a sketch of a knock-off link for tail-rope haulage. When the rope has to be detached, a split cotter at A is removed, and the link B is knocked off by a man or boy with a small hammer. There is generally a joint in the J hook, as shown at D, to prevent it from coming in contact with tram rails and sleepers after being disconnected from the tub, and causing it to assume a straight position instead of being J-shaped.

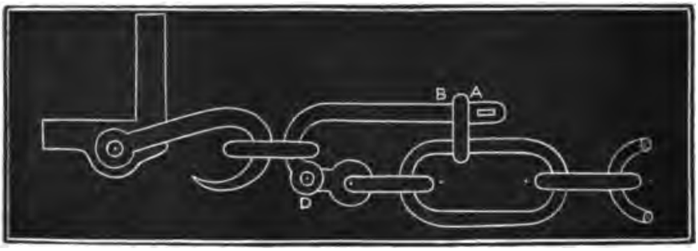


Fig. 261.

643. Give a short description, with sketch, of working incline planes and balance-brows where the seams lie at a high gradient—say, 40 degs.

When coals have to be hauled up an incline plane having a gradient of 40 degs. or over, the tubs are placed on a cage, as shown in fig. 262. This cage is drawn up and let down by an engine just as on ordinary inclines, and, when at the top or bottom or at intermediate levels in the incline, it forms a level platform with the roadways, the tubs being taken off and put on as they would be put on or taken off the cage at the pit shaft. Sometimes cages are made to hold four tubs, in which case they are double-decked (the sketch represents a single-deck cage). When balance brows are worked at a gradient of 40 degs. or over,

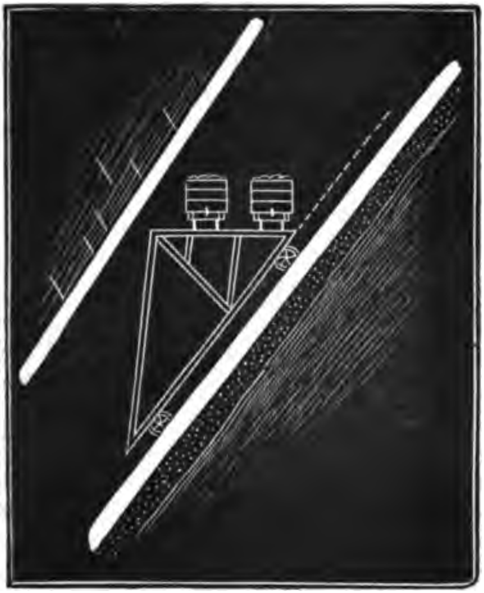


Fig. 262.

the tubs are placed on the cage, as shown in the sketch, and counter-balanced by a heavy balance-box working on another set of tram rails in the balance brow. At the top of the brow a strong brake-wheel or drum is fixed, with a powerful brake attached, similar to that illustrated in fig. 232. The attendant at the brake can bring the cage to a stand (at will), at top or bottom or at intermediate levels in the brow to allow the tubs to be taken off or put on the cage.

[I would recommend surface hands, such as carpenters and smiths, to make themselves acquainted with the replies to the following questions.]

644. Describe the method of blacksmiths' hammer signals?

The following is a description, from the *Hardware Reporter*, of the signals the blacksmith gives his striker when at work: When the blacksmith gives the anvil quick, light blows, it is a signal to the helper to use the sledge or to strike quicker. The force of the blows given by the blacksmith's hammer indicates the force of blow it is required to give the sledge. The blacksmith's helper is supposed to strike the work in the middle of the width of the anvil, and when this requires to be varied the blacksmith indicates where the sledge blows are to fall by touching the required spot with his hand hammer. If the sledge is required to have a lateral motion while descending, the blacksmith indicates the same to the helper by delivering hand-hammer blows in which the hand-hammer moves in the direction required for the sledge to move. If the blacksmith delivers a heavy blow upon the work and an intermediate light blow on the anvil, it denotes that heavy sledge blows are required. If there are two or more helpers, the blacksmith strikes a blow between each helper's sledge-hammer blow, the object being to merely denote where the sledge blows are to fall. When the blacksmith desires the sledge blows to cease, he lets the hand-hammer head fall upon the anvil and continue its rebound upon the same until it ceases. Thus the movements of the hand-hammer constitute signals to the helper.

645. State, in short, the difference between the blacksmith's sledge, the striker's hammer as used in blasting rock, the pattern-maker's hammer and the stonemason's mallet, with the reason for such difference?

The handle of the blacksmith's sledge is a long one, the eye of the hammer being nearer the pene or narrow end than it is to the broad face end. The reason for this is that the striker delivers most of his blows in a vertical direction, using mainly the face and not the pene of the hammer, and by having the eye, and consequently the handle nearest the pene end, the face end naturally hangs downwards, because, as held by the handle the face end is the heavier, and needs little if any effort to keep it downward. The striker's hammer as used in blasting rock, has the eye in the middle of its length, the striker using both faces of his hammer; the stale or handle is placed centrally, balancing both faces equally. The pattern-maker's hammer has a long and slender stale—long, that it may reach into recesses and cavities, and slender, because being long it has weight enough without being stout. The stonemason's mallet is circular, and has a short stale; it is made circular, so that it can be used over the whole circumference without the chisels wearing holes in the wooden face; the stale is short, in order to deliver just the kind of blow required, and with force sufficient, but without allowing a great leverage.

646. Which kind of nails do you consider best for pattern-making and carpentry work—the cut nails or wire nails?

Wire nails are very favourably regarded and are used in preference to cut nails, notwithstanding the extra cost on account of their superior tenacity. The iron for cut nails, after being rolled, is slit or cut lengthwise to a width adapted to the length of the nail to be cut. The nails are then cut directly across the fibre, which the iron has acquired by rolling, and the weakest part is found where the strongest should be. Ordinary cut nails will not drive into seasoned hard wood without "crippling," even under direct blows, and when the blow of the hammer is slightly on one side they snap, having no tenacity. The weakness of these nails is evidenced by the fact that it is almost impossible to straighten one that has been drawn from the wood, and then drive it in again, for in many or most instances the nail will break in drawing. On the contrary, wire nails may be twisted into cork-screws, and then be straightened and re-driven. They are not only tough, but they are stiff, and will penetrate hard wood where the cut nail would break or double up. In every respect the fibrous nail is better than the cross-cut nail.

647. Can you give the ingredients of a good varnish for patterns?

Yes; a varnish has been invented in Germany for foundry patterns and machinery. It dries leaving a smooth surface almost as soon as it is applied. It is thus prepared: 30 lb. of shellac, 10 lb. of Manilla copal, and 10 lb. of Zanzibar copal are placed in a vessel, which is heated externally by steam and stirred during from four to six hours, after which 150 parts of the finest potato spirits are added, and the whole heated for four hours to 67 degs. This liquid is dyed by the addition of orange colour, and can then be applied as a paint on wood. When used for painting and glazing machinery it consists of 35 lb. of shellac, 5 lb. of Manilla copal, and 150 lb. of spirit.

648. Can you give the ingredients of varnish to clean and polish machinery?

Yes; take 1 oz. of camphor, dissolving it in 1 lb. of melted lard, take off the scum and mix in as much fine black lead as will give it iron colour. Clean the machinery and smear it with this mixture. After twenty-four hours rub clean with a soft linen cloth, and the machinery will be found to have a good polish and will not rust under ordinary circumstances for a considerable time.

649. Do you know a simple method of writing or engraving on steel tools?

Yes; first clean the tool with oil, then spread a coating upon it of melted beeswax. The writing or engraving can then be done on the beeswax with any sharp instrument, and the lines and marks thus made should be painted with a fine brush dipped in a liquid made of 1 oz. of nitric acid and $\frac{1}{8}$ oz. of muriatic acid. When the written lines are filled with this liquid the tool should be allowed to remain five minutes, and then be dipped in water and afterwards cleaned.

650. Give a short description of the process of case-hardening as applied to parts of machinery that have to stand great wear and tear.

Case-hardening is practically the converting of the surface of iron into steel. The process is very useful and should be understood by every smith, as by it the surface of iron may be made harder than the hardest steel, without losing its malleability. One of the prime requirements in case-hardening is that the article shall be well polished; the finer the polish the better the results. When polished, articles are embedded in coarse charcoal powder in a wrought iron box, which should be air-tight, or sometimes a pipe is employed, and this is really preferable, because it can be turned, and the heat be applied uniformly. The box or pipe is exposed for some twenty-four hours to a gentle cherry-red heat. By exposing the articles to the heat for the period named, a hard surface of about ⅛ in. in depth is obtained. If so much time cannot be given to the operation, or if deep hardening is not required, the articles may be embedded in animal charcoal, or in a mixture of animal charcoal and wood charcoal, and exposed for a much less period. Four or five hours will then be found sufficient to make a good surface of steel.

651. Give a description of the method of tempering mining picks to be used in hard rock, such as sinking and tunnel driving.

The tempering of a pick is a very nice piece of work, and should be done with great care. In the first place a good charcoal fire is necessary; next, good steel; and then a good light hammer with a smooth-faced anvil; and, lastly, a man is needed with a good keen eye, considerable experience and excellent judgment. No good pick can be turned out if any of the above essentials are wanting in the process. A pick should never be "upset," or hammered endwise, nor raised above a full red heat. The steel should be, moreover, heated as quickly as possible, as long exposure to the heat—even if the heat is not in excess—injures its texture. Many blacksmiths find great difficulty in tempering picks, because they do not choose good steel. After being heated the pick must be worked with care, special pains being taken, in drawing it out, to hammer on all sides alike, in one place as much as another, and on one side as much as the other. When ready for hardening it should be heated in the blaze of a charcoal fire until red hot, and then plunged into cold rain water, and kept there until it is nearly cold; but if kept too long in the water or until it is quite cold the corners are liable to fall off. Some blacksmiths use hot water; no salts of any kind should exist in the water, but the water should be cold; if the water is warm and a little ice be thrown in to chill it, the tempering will be all the better. Pure soft water for hardening will make a tougher pick, and one less liable to crack at the edges than where salt water is used. The last hammering of a pick should always be given on the flat sides across, close to the edges and then up each side about an inch. By so doing the corners will be less liable to crack off.

652. Give a description of tempering springs.

A correspondent of the *Blacksmith and Wheelwright* says: "My way of tempering springs for use above or below water is as follows: I first forge from good cast steel, hammering edgewise as little as possible, and then heat evenly in a charcoal fire. I do not blow the bellows but simply lay the spring in the fire and let it come to a cherry red. I next dip it in pure lard oil, then take it out and hold it over the fire while the oil blazes all over the spring. I then lay it in the dust on the forge and let it remain there until it is cold. Then the job is done. Springs should never be filed crosswise, but should always be filed lengthwise for a finish."

653. Describe the method of using a file when filing.

In using a file the operator should firmly grip the handle with the right hand and lay the thick part of the left hand on the other end of the file to give the necessary pressure according to the character of the work being done, at the same time keeping his right elbow close to his side in a straight line with the file. In the backward motion the file should not be allowed to bear on the article; in the forward motion the pressure should be uniform on the file from end to end; if more pressure is put on one part than on another the file will soon refuse to do even work. If in the backward motion the file is allowed to bear on the article it is crowded forward in proportion to the amount of force applied; hence, only a few strokes are needed to break off the outer or keener edge of the tooth, whereas if the file were not allowed to touch, the steel would continue to bend toward the operator, and would wear off smoothly and not become uneven or jagged along the outer edge. Then again, these minute and evenly-made furrows in the best-made tools soon become, as it were, logged by small bits of worn-off steel which have the temper drawn by the head generated by friction during rapid hard work. These little particles soon aggregate to such an extent that the file is rendered useless for nice even work.

654. What power would be required to raise a weight of 3,000 lb. by a pair of four and five sheaved blocks. the four being the rising block?

As there are nine cords leading to and from the rising block, it will be $\frac{3,000}{9} = 333$ lb., the power required.

655. To raise a weight of 4,256 lb., the amount of power to effect this being 500 lb., what kind of blocks would it be necessary to employ?

The power required will be $\frac{4,256}{500}$ lb. = 8·51 cords, so there must be four sheaves, or nine cords in the rising block.

656. Give the reason why the differential pulley block does not overhaul.

Because more than half the power applied is lost by friction.

657. Give a rule for finding the mechanical effect of a crane.

Rule:

$$\frac{\text{Diameter of circle described by handle} \times \text{product of number of teeth in all the wheels}}{\text{Diameter of barrel} \times \text{number of teeth in all the pinions.}}$$

658. Suppose the handle of a crane moves in a circle 3 ft. diameter. On the shaft there is a pinion of twelve teeth, working into a wheel of 180 teeth. On the shaft carrying the latter is a pinion of twenty teeth working into a wheel of 200 teeth. The last wheel carrying the barrel being 1 ft. in diameter, what is the power of the crane?

$$\frac{3 \times 180 \times 200}{1 \times 12 \times 20} = 450.$$

The friction of a crane is not great; at any rate, it is less than one-half, because the weight will run down if allowed to do so. Nothing will overhaul or run back when the friction is more than half, as is the case in differential pulleys, blocks and screws. Practically, in a well-constructed crane the loss by friction will not be more than ·25 to ·20.

659. Describe the method of soldering.

The following instructions, taken from the *Mechanics' Workshop Handybook*, will be useful:—The term soldering is generally applied when fusible alloys of lead and tin are employed for uniting metals. When hard metals, which melt only above a red heat (such as copper, brass, or silver) are used, the term brazing is sometimes used. Hard soldering is the art of soldering or uniting two metals or two pieces of the same metal together by means of a solder that is almost as hard and infusible as the metals to be united. In some cases the metals to be united are heated, and their surface united without solder by fluxing the surfaces of the metals. This process is then termed burning together. Some of the hard soldering processes are often termed brazing. Both brazing and hard soldering are usually done in the open fire on the brazier's hearth. A soldering joint is more perfect and more tenacious as the point of fusion of the solder rises. Thus, tin, which greatly increases the fusibility of its alloys, should not be used for solders, excepting when a very easy-running solder is wanted. Solders made with tin are not so malleable and tenacious as those prepared without it.

Plumbers use solder composed of two parts of lead and one of tin, and a very slight variation in these quantities makes a very considerable difference in the working, and also in the soundness of the joint. If a slight excess over the above proportion of lead is used, the solder is more difficult to work, and the joint, when made, frequently leaks, the water passing the small cellules or pores in the metal, and the joint is then said to "sweat." If an excess of tin is used, the solder melts too easily, and considerable difficulty is found in keeping it on the joint, and it cools so suddenly that the joints always look rough and ragged at the ends. They sometimes require trimming up to make them look better; this solder also keeps running, and then congealing, in such a way as to be difficult to keep it at a workable heat. Small portions of the metal also keep sticking to the cloth used for moulding, technically called wiping, the joint or seam, as the case may be. Plumbers' solder, with the above proportions, on being melted, and then allowed to cool, will generally exhibit several bright spots on its surface, due to the two metals partly separating. These bright spots are generally a very sure guide as to the proper quantities of each metal used. If none are seen, it is too coarse; and if too many are seen, it contains too much tin and is said be too fine. If the spots are small, the metal may not be good, although it may have beyond its proper quantity of tin; but if the spots are about the size of a threepenny-piece, the solder very rarely fails to work well. In uniting tin, copper, brass, &c., with any of the soft solders, a copper soldering-bit is used. This tool and the manner of using it are well known. In many cases the work may be done more neatly without the soldering-bit by filing or turning the joints so that they fit closely, moistening them with the soldering fluid described hereafter, placing a piece of smooth tinfoil between them, tying them together with binding wire, and heating the whole in a lamp or fire till the tinfoil melts. Pieces of brass are often joined in this way, so that the joints are invisible. With good soft solder almost all work may be done over a spirit lamp, or even a candle, without the use of a soldering-bit. Advantage may be taken of the varying degrees of fusibility of solders to make several joints in the same piece of work. Thus, if the first joint has been made with fine tinner's solder, there would be no danger of melting it in making a joint near it with bismuth solder. The fusibility of soft solder is increased by adding bismuth to the composition. An alloy of lead 4 parts, tin 4 parts, and bismuth 1 part is easily melted; but this alloy may itself be soldered with an alloy of lead 2 parts, bismuth 2 parts, and tin 1 part. By adding mercury a still more fusible solder can be made. Equal parts of lead, bismuth, and mercury, with 2 parts of tin, will make [a composition which melts at 122 degs. F.; or an alloy of tin 5 parts, lead 3 parts, and bismuth 3 parts will melt in boiling water. In melting these solders melt the least fusible metal first in an iron ladle, then add the others in accordance with their infusibility. It is convenient—and, in fact, often necessary—to have solders which will melt at different degrees of temperature, to avoid the risk of spoiling the work by subjecting it to too great a heat, when, with a little easy-flowing solder, there would be no danger.

APPENDIX TO CHAPTER X.

Electricity has now been practically applied to pumping in mines. Some months ago the technical papers contained descriptions of two pumping plants, in which the energy was transmitted from the surface to the pit bottom by electricity. The motor (fig. 263) and dynamo for one of these were made by Messrs. Immisch and Co., of Kentish Town, London, and the work was carried out under their superintendence. The other was designed and erected by Mr. Brain, of the Trafalgar Colliery. Both of these installations are interesting as practical successes. Messrs. Immisch and Co. have now laid down another pumping plant at Messrs. Locke and Co.'s St. John's Colliery, Normanton, which is designed to cope with a salt-water feeder of 5,100 gallons per hour, at a vertical depth of nearly 900 ft. below the surface. The water is raised at one lift and at a rate of about 7,200 gallons per hour. Since the pressure on the ram faces is about 400 lb. per square inch, specially-designed pumps were required, and the electrical plant had to be designed to suit the conditions obtaining. The pumps are differential, with two 6 in. and two 4½ in. rams. When doing full duty the pumps run at twenty-five revolutions per minute. It was found, by a preliminary trial of a smaller plant, that the load on the rams varied largely at different parts of the stroke. To avoid the heating that would be entailed in an ordinary motor working under a large current with a regular and rapid variation in its intensity, it was necessary to specially design the field and armature. The output of the dynamo is 53-horse power, and the efficiency between the actual useful work and the output of the dynamo is 62 per cent. approximately. The commercial efficiency or ratio of useful power in the dynamo cannot be less than 50 per cent. approximately. This efficiency includes all the losses in transmission, viz., that in the dynamo, leads, motor, gearing, pumps, and rising main pipes. Messrs. Immisch claim that this shows an efficiency at least double that where compressed air is used. The dynamo and motor also cost something like 25 per cent. less than compressors, accumulators, and air engine to do the same work. The question of prime costs is an important one; but perhaps that of maintenance and security of running is more important still, in cases where break-downs may entail very serious consequences. With electricity the cost of maintenance, judging from a large and varied experience of its application to nearly all kinds of machinery, is practically limited to the wear of brushes, commutators and bearings. The motor is wound according to Immisch's patent, and runs practically sparkless, with a constant lead, although the load is varying 30 per cent. during every revolution of the pump. The speed of both dynamo and motor is 450 revolutions per minute. The engine is a compound semi-fixed, by Messrs. Robey and Co., of Lincoln, and works at a boiler pressure of 140 lb. per square inch. It is 30-horse power nominal. That the plant is a success may be judged from the fact that Messrs. Locke and Co. have given an order for two new machines of the same power. The new plant to be used will work an endless rope of an engine-plane by day, and will be ready for pumping at night if required.

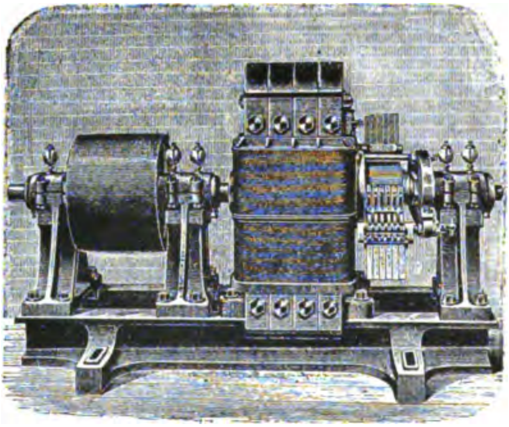


Fig. 263.

Fig. 263 is an Immisch motor, designed to work electromotive (fig. 257) experimentally constructed by Mr. G. Blake Walker, of Barnsley, and electrically fitted up by Messrs. Immisch and Co. The locomotive carries its power along with it, stored up in a number of accumulators. Trials made on the surface are promising enough, but the system has not been tested underground.

CHAPTER XI.

PUMPS, SHAFTS, ROPES, CAGES, &c.

660. What is a pump?

A contrivance for raising liquids or for removing gases from vessels.

661. Who discovered the principle of the common pump?

Galileo first suggested that the atmosphere might have weight, and verified his theory by condensing air in a copper vessel, which was found to increase in weight in proportion to the quantity of air it contained. Galileo's pupil, Torricelli, followed up his master's experiments, and to him we owe the explanation of the working of the common pump.

662. Explain the principle of the common pump?

Fig. 264 is a sketch of a pump, with glass working barrel, through which its action may be seen. A is the handle or pump rod, B is the piston or bucket, C is the clack or second valve below the piston, D^1 is the working barrel, E is the windbore or suction pipe, F is the spout or outflow, G is the well or water tank, H is the stand or frame upon which the pump is fixed. By lifting the piston the valve, B, closes, thereby tending to produce a vacuum, but the pressure of the air upon the water in the tank, G, forces more water into that part of the working barrel, D^2, where a vacuum would otherwise be formed; at the same time the outflow of water takes place at F. The piston being forced down, the valve, B, opens and the water rushes through, while the clack, C, or second valve, closes and prevents the water from returning into the well or tank, G.

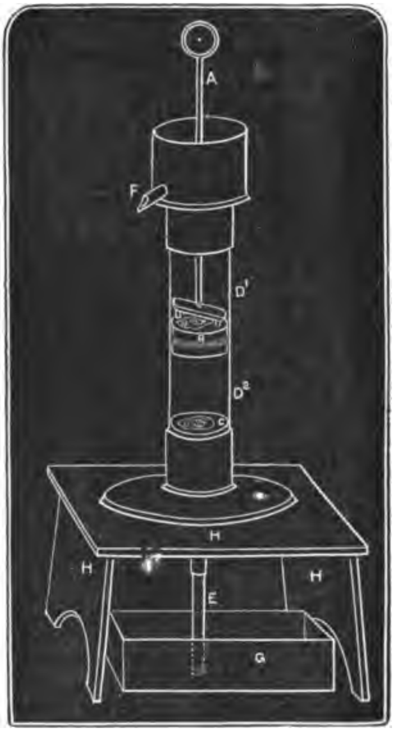


Fig. 264.

663. Explain some of the principal parts of a pump and their action.

The pump is a long iron cylinder, varying in diameter from about 6 in. to 20 in. or more, according to the magnitude of the drainage; but, generally, about 9 ft. long. This is termed a working barrel, and is sometimes lined with brass. The thickness of the iron for this and other parts, such as pumps, door-pieces, &c., depends on the size of the work and the length of the lift. The clack-piece is that part of the pump in which the clack is placed. There are a great variety of forms in clacks, but the forms most generally used are represented in figs. 265, 266, 267 and 268, sometimes termed "butterfly" valves. The bucket is the part that lifts the water, and works in the working barrel. It is graithed with leather to make it watertight, and is furnished with two wings or falls on the top, made of leather and iron, which work on hinges in the centre of the bucket, similar to those shown at A A, fig. 267, on the clack. The windbore is a cylinder similar to a pump, except that at the bottom there are numerous holes, called snore-holes, for the admission of water. There are two kinds—a flat bottom, used for the plunger lift, and the sinking or egg-end windbore, used with the bucket lift. The latter is known as the slide windbore (see figs. 269 and 270), and is provided with a stuffing-box and gland, *g*; *p* is the packing; *a* is where the windbore projects, turned

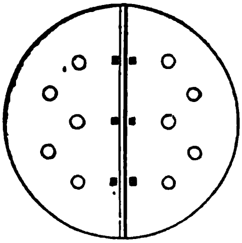


Fig. 265.

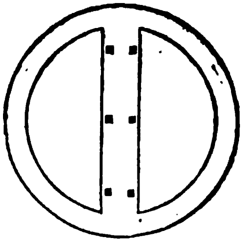


Fig. 266.

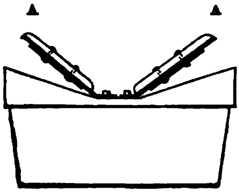


Fig. 267.

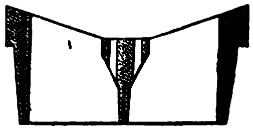


Fig. 268.

to fit the slide. Spear-rods are made of wood, about 40 ft. in length, and average from about 8 to 15 in. square, according to size of buckets. They communicate the power from the engine to the bucket, and are fastened together by having spear plates of iron placed up each side, and bolts put through. Bolts, called clink bolts, are also placed through the spears, at right angles to the spear bolts, to strengthen them.

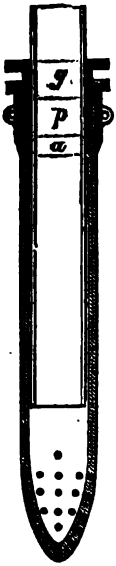


Fig. 269.

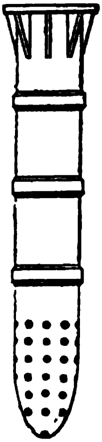


Fig. 270.

664. What regulates the height to which a pump will lift water?

Atmospheric pressure is sufficient to force water through a vacuum 32 ft. high, and it is by virtue of this law that the water finds its way from the windbore into the clack-piece and working barrel.

665. How is the vacuum caused in a working barrel?

The vacuum is caused by the suction of the bucket or plunger in the first instance, and the continuous supply of the water maintains the action by the up-stroke of the rods and the opening and closing of the clacks or valves.

666. Is it possible to produce a perfect vacuum ?

No; a perfect vacuum cannot be produced, for after every effort has been made to exhaust it, some air will remain, but in so attenuated a form as to be for practical purposes *nil.*

667. By doubling the diameter of a pipe, by how much is its capacity increased ?

The capacity of a pipe is as the square of its diameter; therefore, by doubling the diameter the capacity is increased four times.

668. What ought to be taken into account when calculating the thickness of metal in cast iron pipes, to withstand a given pressure ?

Pipes for pumping purposes should be sufficiently strong to resist accidental stress, as well as the normal stress from internal pressure. In calculating the requisite thickness of a cast iron pipe under given conditions, it must be borne in mind that it is not possible always to keep the core perfectly central throughout; therefore, a pipe may have an excess of metal on one side and a corresponding deficiency on the other. As the strength of a pipe is the strength of its weakest part, due allowance should be made for such defects. All pipes, before being used, should be tested by hydraulic pressure up to three times the head or pressure they will be required to withstand.

669. Give a sketch (plan and section) of a good flange for pipes suitable for pumping purposes in pit shafts.

Fig. 271 is a section and fig. 272 a plan of a good flange. Pipes with flanges of this shape fixed in shafts, &c., only require two bolts in each joint, whilst a perfectly tight joint is ensured, the facings being turned slightly cone-shaped and fitting the one into the other; this shape of joint will be found to withstand a very high pressure, as the indiarubber joint-ring cannot be blown out—a very common occurrence in long lifts where the pipes have plain joints.

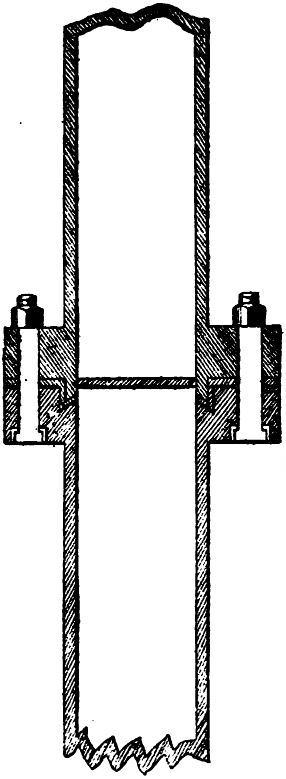


Fig. 271.

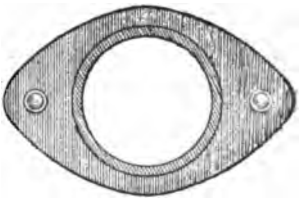


Fig. 272.

670. Can you give a formula for finding the thickness of metal in pipes?

I have always found the following to work well for various diameters and pressures of pipes, and it is one of my own compiling. Let H = the head of water in feet, D = diameter of the pipes in inches, X = the required thickness of metal in inches, ^{x} being a constant quantity equalling ·24 in. Then $X \times \cdot 24^{x} + \frac{H \times D}{10{,}000}$.

671. With a lift or head of water of 480 ft., what should be the thickness of metal in the pipes, supposing the pipes to be 5 in. diameter?

In calculating the requisite thickness of metal for pipes to withstand a pressure or head of water of 480 ft., I should divide the pipes into three lengths—say, 180 ft., 150 ft., and 150 ft. respectively, the bottom length to withstand 480 ft. head of water, the second length 300 ft. and the third length 150 ft. By applying my formula, the thickness of metal will be found to be as follows:—

Example:—$X = {\cdot}24^{x} + \dfrac{480\text{ ft.} \times 5\text{ in.}}{10{,}000}$

480 ft. head—$480 \times 5 = 2{,}400{\cdot}00 \div 10{,}000 = {\cdot}24 + 24^{x} =$ ·48 in. thickness of metal.

300 ft. head—$300 \times 5 = 1{,}500{\cdot}00 \div 10{,}000 = {\cdot}15 + {\cdot}24 =$ ·39 in. thickness of metal.

150 ft. head—$150 \times 5 = 750{\cdot}000 \div 10{,}000 = {\cdot}075 + {\cdot}24 =$ ·315 in. thickness of metal.

The column being divided into three lengths, the metal in the pipes would be thinner as the head or pressure of water became less.

672. Are wooden pipes ever used for pumping and draining purposes?

Yes; in America especially. In one year over 100 miles are said to have been sold by the Wyckoff Pipe Company, of Williamsport, Pa., and their representatives—a large proportion being for extending water systems in cities. In many cases where the wooden pipe has been in use for several years alongside iron pipe, it is said that the wooden pipe has proved superior. The advantages claimed for the wooden pipe for conducting surface water apply more forcibly to its use in and around mines as a conductor of mineral water, because the acids contained in mine water will not affect it. Another important advantage is that anyone can lay the pipe; where the country is very rough, it is often laid on top of the ground, with just enough covering to protect it from the sun and fire, and the sections only require driving together. Pipe manufactured by the firm named for conveying water to boilers, &c., is being generally used. It can be laid for less than one-third the cost of laying iron pipe, and will not burst with frost. As column or suction pipe for draining mines, it has also advantages and is rapidly being introduced for these purposes.

673. Describe a good joint for a bucket door-piece and a clack door-piece?

A good joint for bucket and clack door-pieces can be made from flat iron cut to the shape of the door and wrapped with tarred flannel. I have known such to stand the test of lifts over 300 yards, and answer very well.

674. What is an H-piece?

The H-piece is so-called from its resemblance to the letter H (see figs. 273, 274 and 275). It is usually cast in one piece jointed at the middle by a horizontal passage. The part under the bucket door-piece is considerably larger than the part under the working barrel, in order to receive the valve and to allow space for its action.

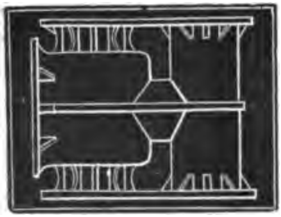


Fig. 273.

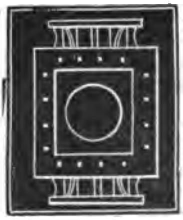


Fig. 274.

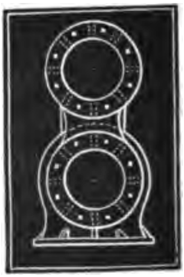


Fig. 275.

675. How many clacks are there to a bucket lift?

There is one clack and a bucket (see fig. 276); A is the bucket, and B the bottom clack.

676. How many clacks are there in a plunger?

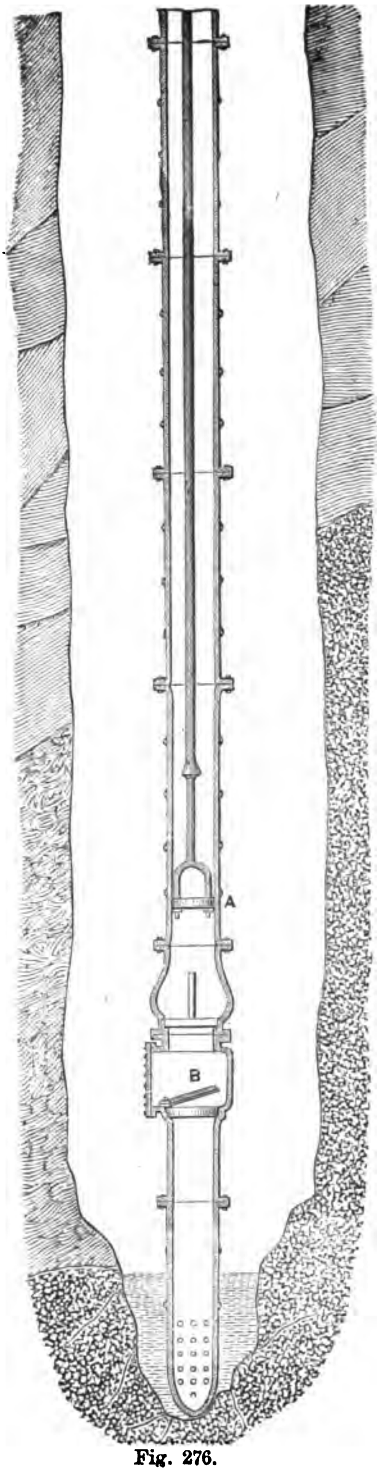


Fig. 276.

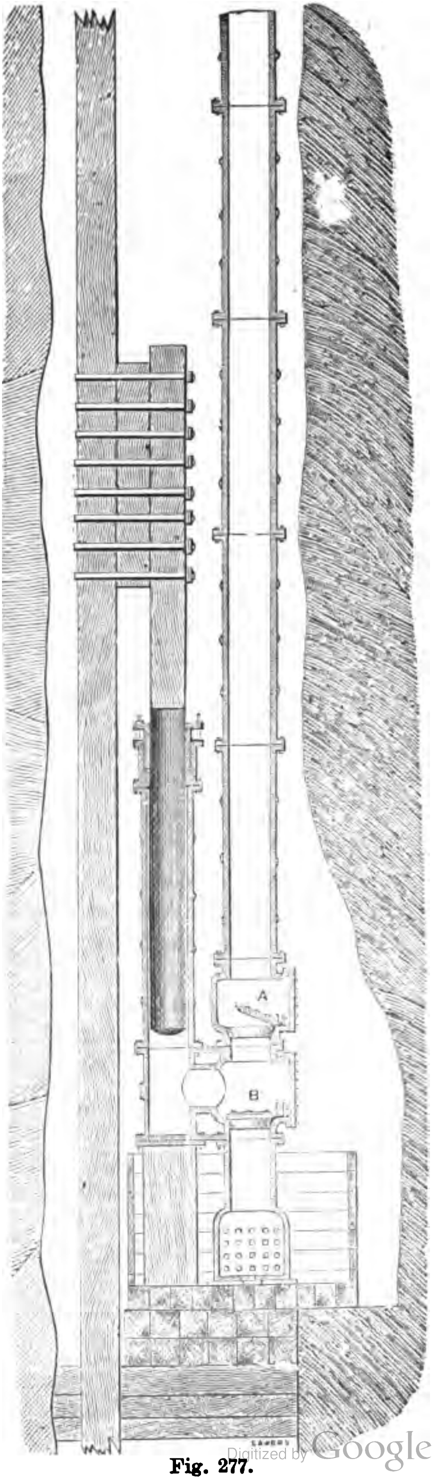


Fig. 277.

Two; the clack A (fig. 277) opens when the plunger descends, the clack B opens when it is ascending, so that it may be understood these clacks are never both open or shut at the same time. Fig. 278 is a plan and section of a pair of 17 in. bucket lifts, showing the engine, L-legs, and other details.

677. What is a differential pumping engine?

The differential pumping engine is so called because it is fitted with differential valve gear of a very effective and ingenious type. It is a compound direct-acting pumping engine, and is the invention of Mr. Davey, of Leeds.

678. What is a centrifugal pump?

The Appold pump, made with curved receding blades, is generally so known, and is commonly termed the revolving pump. The height to which water can be raised in pipes by the centrifugal pump is, if we suppose no other resistance, the height due to the velocity of the circumference of the revolving wheel.

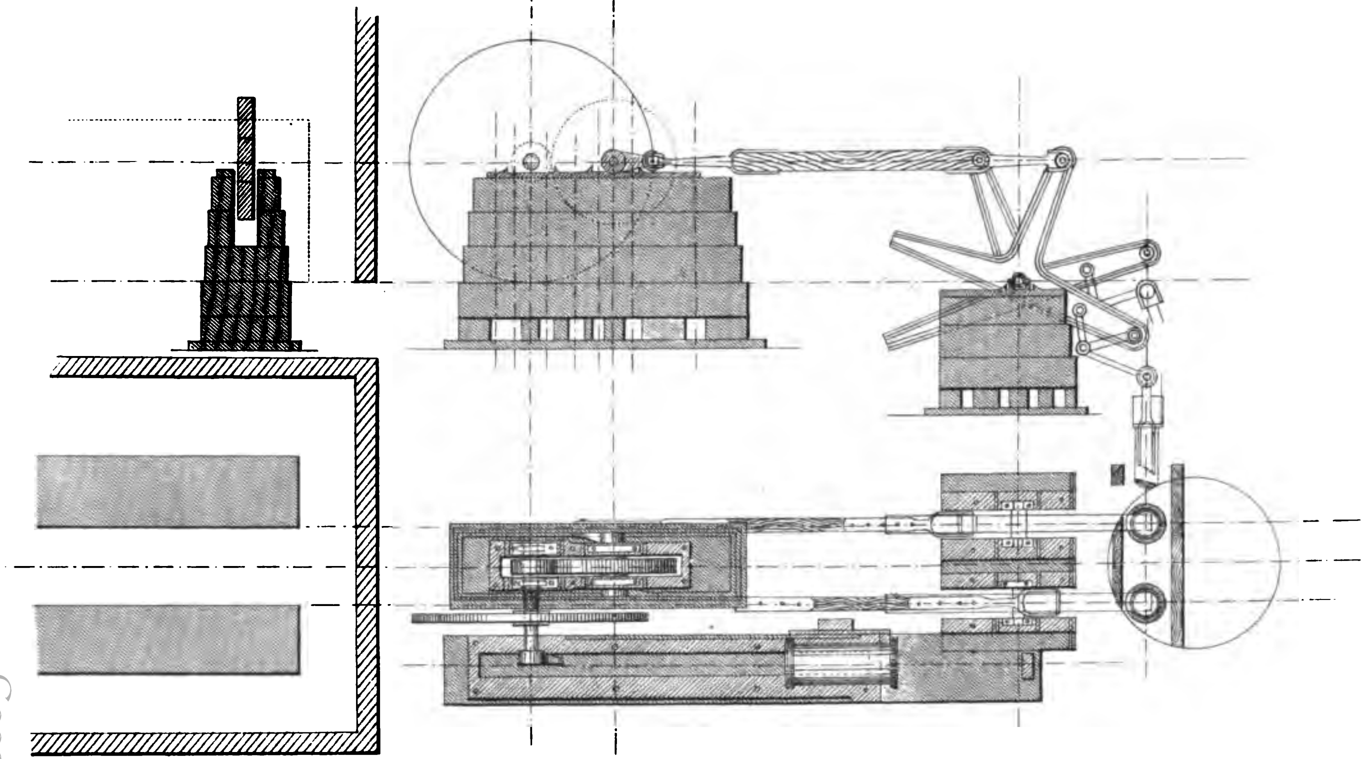
679. What is an endless chain pump?

An endless chain pump consists of a series of paddles, generally about 6 in. square, attached to an endless chain turning on two centres. It can be made to work at any angle or incline. When working vertically the paddles pass through a vertical pipe, and the water is delivered at the top of the pipe.

680. What kind of pumping engine do you consider best for underground drainage generally?

For pumping large quantities of water up pit shafts, the Davey differential pumping engine is by far the best that has come under the author's notice; but for pumping water in underground works the Cameron pumping engine takes less to keep it in repair, is less liable to breakages than any other known pump, and is recommended for its simplicity and durability, and the great quantity of water it will pump; it costs but little to erect, and occupies but a small space.

Fig. 278.



Scale ¼ Inch to 3 Feet

681. Give a rule to find the quantity of water an engine will pump?

The following is the rule:—

H = horse-power of engine.
F = depth of pit in fathoms.
G = quantity of water in gallons per minute.

$$G = \frac{H \times 550}{F}$$

$$H = \frac{F \times G}{550}$$

682. How many gallons per minute will an engine of 170-horse power pump from a depth of 210 fathoms?

By applying above formula:—

$$G = \frac{550 \times 170}{210} \therefore G = 445.$$

683. Give a rule to find the horse-power required to lift any quantity of water.

The following is the rule:—

G = number of gallons to be raised in twenty-four hours.
H = height in feet to which water is to be raised.
H.P. = actual horse-power required.

$$H.P. = \frac{G \times H}{4,752,000}$$

684. Also give a rule to find diameter of pump required.

The following is the rule and formula:—

L = length of stroke in feet.
G = number of gallons to be delivered per minute.
N = number of strokes per minute.
D = diameter of pump in inches.

$$\text{Thus } D = \sqrt{\frac{G}{\cdot 034 \text{ LN}}}.$$

The following are a few useful numbers in regard to pumping:—

D = diameter of pump in inches.
S = stroke of pump in inches.
$D^2 \times S \times \cdot 7854$ = cubic inches.

$D^2 \times S \times$ ·002833 = gallons.
$D^2 \times S \times$ ·0004545 = cubic feet.
$D^2 \times S \times$ ·02833 lb. = fresh water.
Cubic foot of water (62°) = 62·355 lb.
Cubic inch of water „ = ·03608 lb.
Gallon of water „ = 10 lb.
Cubic foot of water „ = 6·2355 gallons.
Cwt. of water „ = 1·795 cubic feet.
Ton of water „ = 35·90 cubic feet.

685. Your spear bolts wearing your pump trees, what would you do with them?

I would line the spears with wood above and below the bolts.

686. What is the difference between a plunger and a drawing lift?

The plunger works with a ram through a stuffing box; the drawing lift works with a bucket.

687. A shaft 170 yards deep makes water, which has to be pumped to surface, and your pumps are divided into two lifts; which would you have at the bottom of the shaft—a plunger or a drawing lift—and why?

I should have a drawing or bucket lift at the bottom of the shaft, so that if the bucket became defective and would not pump, and the water rose above the bucket door, which would prevent the changing of the bucket in the shaft, I might draw the rods and change the bucket at the surface, then loose the new bucket attached to the rods, and commence pumping again; this could not be done with the plunger if the water rose above the stuffing-box or packing-gland, as it would prevent it from being packed if needed.

688. If you were pumping water with a bucket or drawing lift, which would you have the larger—your working barrel, or pump trees—and why?

I would have the pump trees ½ in. in diameter larger than the working barrel, so that in case of the water rising at any time above the bucket door, and the bucket requiring to be changed I could draw it to the top of the lift and change it there.

689. Explain the advantages in a deep shaft of having a series of lifts instead of one long lift.

The advantages of dividing a long lift may be enumerated as follows:—It does not necessitate such frequent change of the bucket; there is less liability to break the spears; the strain on the engine is equalised, and the pressure on the bucket and lower lift is reduced.

690. What is a siphon?

The siphon is a bent tube or pipe (see figs. 279 and 280) for conducting water or other liquid from one level to another. The atmospheric pressure upon the water to be siphoned forces it into the tube as fast as the siphon empties itself through its longer arm.

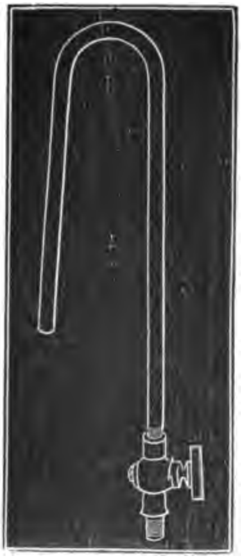


Fig. 279.

The action of the siphon in its application to the drainage of mines may be understood by referring to fig.

281. Supposing from A to B to be an underground incline 180 yards long with a gradient of 2 in. per yard; and supposing A to be the body of water that requires siphoning out of the workings, and B to C the discharge or fall for the siphoned water into the lodge or sump, according to circumstances. At D there is a tap or valve, fixed in the pipes, which can be shut or opened by hand (when the siphon requires starting first this tap is shut), and at E there is an air-pump fixed to the siphon pipes; this pump is used by hand to empty the pipes of air. The pressure of the atmosphere on the surface of the water at A, forces it through the pipes to the tap or valve, D;

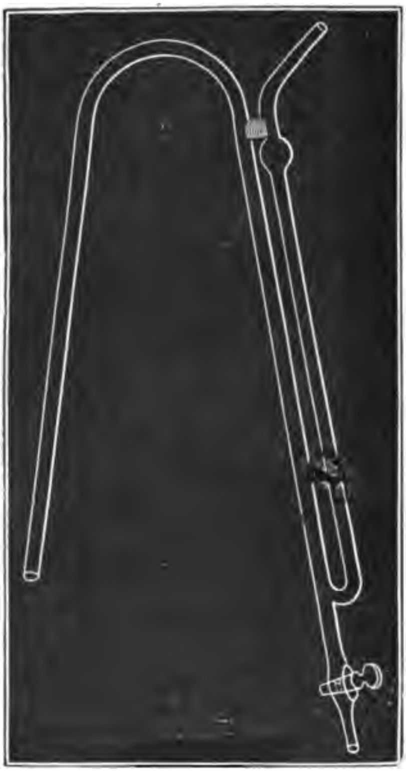


Fig. 280.

then this tap is opened and the siphon commences its work, providing the point C is lower than the point A. I have seen the siphon work very effectually, and siphon great quantities of water from dip workings without the air-pump. This is accomplished by putting in a bottom clack or back-pressure valve at F, and putting a screw plug at the elbow or bend of the pipes at E, in place of the air-pump. This screw-plug is required when the suction or snore end is uncovered by the water; the tap D is shut, and the screw-plug unscrewed out of the elbow, and water poured through the plug-hole to prime the siphon. When the pipes are filled with water the screw-plug is screwed in again, the clack F and the tap D preventing the water from escaping at either end of the pipes. I have known the siphon used for twelve months together without the employment either of the air-pump or screw-plug, by noticing the siphon before it gets at blast, and by shutting the tap D; so that if the siphon is required to start in one hour's time, or in twelve hours, it can be started by opening the tap D.

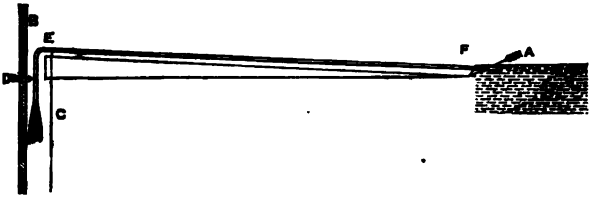


Fig. 281.

691. Can you show by experiment that the atmosphere presses in every direction?

Yes; here is a tumbler (fig. 282) filled with water and covered with a card. If the glass be carefully inverted the water will still remain in the glass, the pressure of the atmosphere upon the surface of the card counteracting the weight of the water in the glass. To illustrate this fact more clearly, the rose of a watering can (fig. 283) may be filled with water; so long as the top hole is closed the upward pressure of the atmosphere on the under side prevents the flow of the water in the rose; the moment the

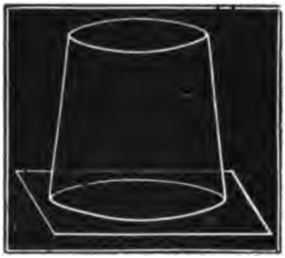


Fig. 282.

finger is removed and the pressure from above allowed to act equally with the pressure from below, the water by its own gravity will pass through the rose.

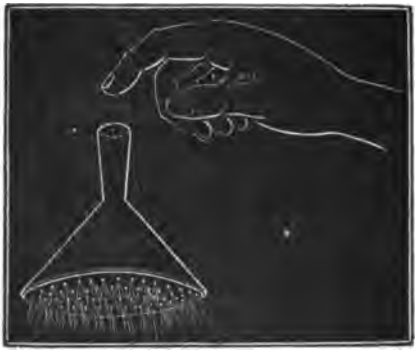


Fig. 283.

692. Over what distance can water be siphoned?

Water can be siphoned from point to point over an obstruction, which, however, must be less than 32 ft. higher than the surface of the water. The quantity of water depends on the difference of the level at the opposite sides of the obstacle, and is not influenced by the height of the obstacle, except so far as is due to the increase of friction consequent on the increase in the length of the pipe. That is to say, water may be siphoned any distance providing the rise is not more than 32 ft., and providing also a sufficient fall at the discharge end can be secured.

693. A siphon is placed in a mine having sufficient fall at the outlet or discharge end, but it fails on trial to work properly; what is the probable cause?

It may be that the vertical height from the water to be lifted to the highest point of the siphon is more than 32 ft. (the exact height will be affected by the tidal elevation of the locality); or there may be a leak in the pipe, or the discharge end of the pipe may allow the water to escape faster than it can ascend the rising end of the siphon, or from great length in the rising pipe the friction may reduce the expected flow.

694. What quantity of water would a siphon discharge through 3 in. pipes, say 900 ft. in length, the rise from supply end to summit being 8 ft., the fall from summit to discharge end 17 ft.?

The quantity depends on the difference between the surface level of the water at supply and delivery ends, A C, fig. 281. The theoretical velocity, in feet per second, is as the square root of the product of the space fallen through in feet divided by 64·4. For example: With 900 ft. of 3 in. siphon, from summit to supply the fall is 8 ft. and from the summit to discharge is 17 ft.; then the difference is 9 ft. and the theoretical discharge would be as if the water were flowing through an orifice 3 in. in diameter and with a head of 9 ft., and the velocity per second would be such as a body would acquire by falling 9 ft. freely in space. $\sqrt{64{\cdot}4 \times 9} = \sqrt{579{\cdot}6} = 24{\cdot}2$ ft. velocity per second, or 290·4 in. per second. The diameter of the pipe being 3 in., the area of the orifice is a trifle over 7 square inches. $290{\cdot}4 \times 7 = 2{,}032$ cubic inches or 8·8 gals. per second or 528 gals. per minute, but in the above calculation the friction in the 900 ft. of pipes has not been taken into account, and to get the actual discharge the following formula is given:—

$W = \frac{\sqrt{D^5 H}}{L} \times 4{\cdot}71$, when $D =$ diameter of pipe in inches. H = head of water in feet. L = length of pipe in feet. W = cubic feet of water per minute.

$$\text{Then } W = \frac{\sqrt{243 \times 9}}{900} \times 4{\cdot}71 \text{ or } 14 \text{ cubic feet}$$

or 104 gallons per minute, which shows a loss of 424 gallons per minute, caused by friction.

695. Can you give a plan of a good steam crab or capstan engine for pump work?

The drum of a steam capstan being required to travel at a very slow speed and to lift very heavy weights, to avoid having a large steam engine the power is obtained by gearing, which also gives the slow motion to the drum. By arranging the gearing as shown in fig. 224 the power of a small engine can be increased to the power required. When the engine is not in use for capstan work, it may be thrown out of gear, and set to drive a saw-mill, lathe fan, &c.

696. You have a winding engine winding from two pits, a single cage being in each pit, and you want to set one pit off to sink down to a lower seam; there being no room in the other pit you have to put in and work a balance weight; give sketches showing position of balance weight, &c., that you would have to work in the pit set off for sinking, supposing there to be a separate engine employed for sinking, the winding engine being used to work the balance weight and wind coal from the other pit.

Figs. 284 and 285 are a plan and section of the balance weight, &c., that I would have as required in the above circumstances. A is the hoppet, hanging in the centre of the shaft, B B is the balance weight, C C are the rods in which the balance weight slides up and down, D D are baulks of timber to which the rods are secured by screws, one at the bottom as far as the balance weight travels downwards, and the other at the top of the pit as far as the balance weight will go upwards; E is the rope attached to the winding engine from which the balance weight is

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suspended; F F is a hole cast through the centre of the balance weight, a bar of iron going through the hole and taking the end of the rope.

697. If your engines are too small or under their work, what system of balancing would you adopt?

There is probably no better method of balancing than the endless rope system. This consists of a tail rope attached to the lower ends of the cages; an old cast-off rope is very suitable, there being no strain upon it other than the weight of the rope itself. If the tail rope is of the same diameter as the winding rope, it will form a perfect counterbalance in all parts of the winding. Generally a pulley is placed in the sump, round which the tail rope passes, the pulley being free to move upwards or downwards between guides.

698. Give a short description of the Kœpe system of winding with balance ropes.

In this system there is a grooved pulley on the engine shaft, round which the winding rope passes, one end being attached to one cage, and the other end to the other. The pulley on the drum shaft has its rim covered with hard wood grooved to receive the rope. The balance rope is fixed to the lower ends of each cage, and passes round a pulley in the sump in a similar manner to the endless rope system described above.

699. What advantages are claimed for the Kœpe over the ordinary system?

It is claimed for the Kœpe system (1) that it gives a perfect counterbalance in all parts of the winding; (2) that smaller engines and a smaller engine-house are necessary; (3) a reduced length of winding rope; (4) no drum is needed, that being supplied by the pulley described above.

700. Produce a sketch showing the shaft arrangements and position of rods, cages, &c., where two double-decked cages are worked with one box on each deck.

Fig. 286 is a sketch of rods and cages in position in the shaft. Figs. 287 and 288 are cages with the tram-boxes

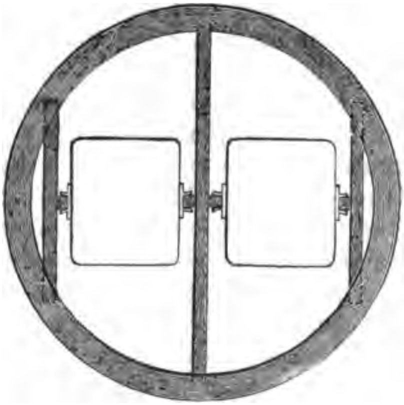

Fig. 286.

in, adapted for fig. 286, when double-decked cages, with two tram-boxes in each deck, are used. For a very good

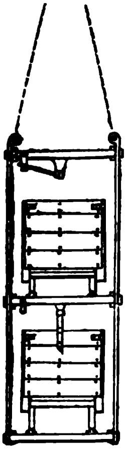

Fig. 287.

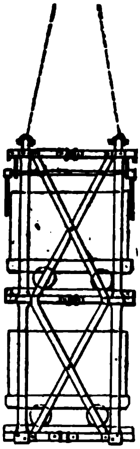

Fig. 288.

design of cages, and to understand the way in which the rods are secured, when wooden ones are employed, see figs. 289 and 290. Cages are generally made of iron, but steel is now coming largely into use on account of its superior strength, lightness and durability.

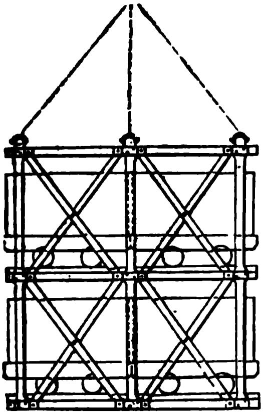

Fig. 289.

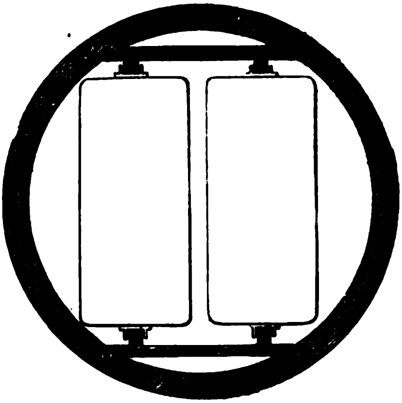

Fig. 290.

701. Give sketches and description of good self-acting catches for holding tubs in the cages whilst ascending or descending the shaft.

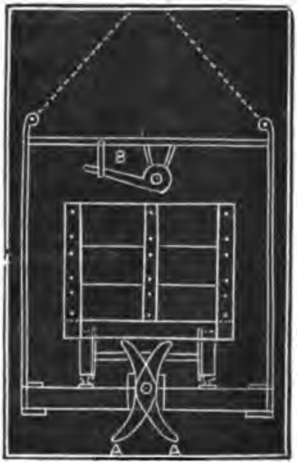

Fig. 291.

The catches shown in figs. 287, 288, 292 and 293 are of the kind usually adopted at collieries. The best catches that have come under my notice are illustrated in fig. 291.

The lower ends of the catches, A A, are made much heavier than the top ends, so that while the cage is travelling up or down the shaft they are held in position as shown, the top ends projecting in front of the tub, the lower ends projecting below the bottom of the cage. When the cage reaches the pit-bottom the lower ends of the catches first come in contact with the support upon which the cage has to rest,

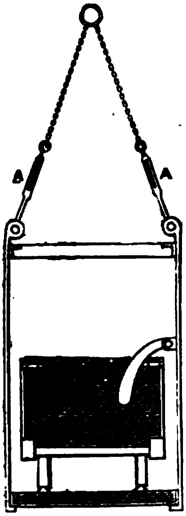

Fig. 292.

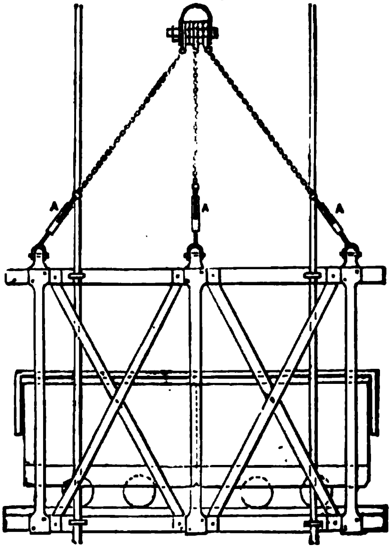

Fig. 293.

and they are forced into an inclined position, thus bringing the top ends of the catches clear of the tub in the cage; the same operation takes place when the cage is wound to the pit-top and rests on the props or supports. As an extra security an additional catch, as shown at B, may be introduced, which would have to be lowered and raised by hand.

702. Do you know of any safety appliances to prevent accidents in shafts in case of the rope breaking or when the cage becomes detached from the rope ?

Many safety catches are in use, but the following is a description of the best that has come under my notice. Across the top of the cage are placed two strong shafts fixed in pillow blocks bolted to the cage frame at each side, and so far apart that their ends project on each side and a few inches from the guides. On the end of each shaft is keyed an eccentric cam of small diameter having its face serrated with teeth like a saw; the distance from the shaft or centre of motion of the cam is such that the short side just clears the guide; consequently, when the two shafts are turned inwards and downwards, the cam is thrown in against both sides of the guides. A spiral spring is coiled around each end of both shafts in opposite directions, like right and left-handed screws, and their tension acts in twisting the shafts, so as to throw the cams in against the guides. A small wheel is keyed on the middle of each shaft, with a chain fastened in its rim and passing around it in the opposite direction to that in which the springs act, the end of the chain being connected to the main clevis shackle or D-link of the winding rope. When the cage is suspended, these chains are so adjusted that they hold back the springs and keep the cams clear of the guides, but if the rope should break or become detached from the cage, the chains falling slack release the springs, which instantly twist both shafts and throw the face of the eccentric cams against the guides with great force. This causes the teeth to bite into the guide, and the weight of the cage acting through the shaft, forces the increasing throw of the cams in between the shaft and guides like a wedge, so that the heavier the cage the tighter it jams, and as the guides are caught on both sides, there is no tendency to split or force them out of position. These catches will act on iron or wooden guides.

Having the same end in view—namely, the prevention of accidents through the breaking of ropes or chains—Mr. E. Ormerod, of Atherton, near Manchester, has, after lengthened experience, invented a more efficient safety cage than those previously in use. The principal advantages claimed for this safety cage are that wear upon the working parts is reduced to a minimum, as they do not move except the winding rope or chain becomes broken, and the grips do not touch the guides at the top and bottom of the shaft as most others do, to the destruction of the guides. The self-acting catches or grips are thrown into action by means of a spring or springs, the movement of which, under ordinary conditions of raising and lowering, is counteracted or overcome by means of a weight; but in the event of a rope or chain breaking, the cage being no longer suspended, its momentum overcomes or neutralises the weight, releases the spring, which throws

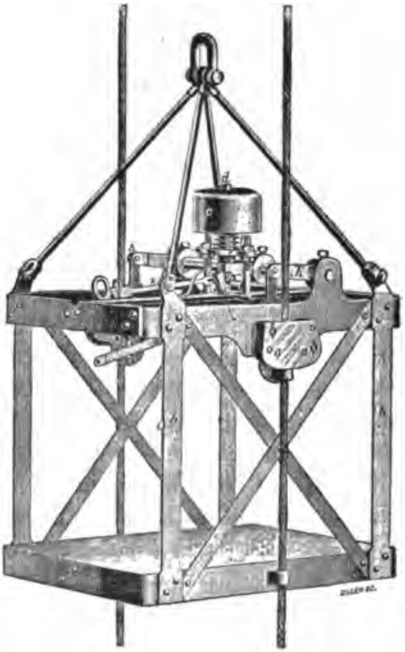

Fig. 294.

into action the catches or grips, and the fall of the cage is arrested. The cage is illustrated in fig. 294. A dead weight, *c*, is fixed at the upper end of a rod or spindle, *d*, which passes vertically through a hole in an adjustable plate, *e*. Above this plate and around the spindle is a coiled spring, *f*, having a tendency to lift the spindle, *d*, but held down by the weight, *c*. The position of the plate, *e*, can be adjusted by means of the two studs so as to increase or decrease the power of the spring, *f*, as may be required. Below the adjustable plate, *e*, the spindle, *d*, is provided with a stud or projection, *g*, which acts upon the lever, *h*, which works the catches or grips, *a*. In ordinary working, this lever, *h*, remains down and holds the catches or grips out of action, but should the rope or chain break, and the cage begin to descend, the coiled spring, *f*, overcomes the weight, *c*, and the stud, *g*, raises the lever, *h*, and puts the catches or grips into action; a spring catch comes under the end of lever, *h*, which prevents the latter from falling and releasing the catches or grips. The catches can be put into or out of gear, as may be required, by means of a sliding notched bar, *k*, which will hold them fast in either position. An arrangement is also made whereby the person in charge can, by means of the lever, *l* (or by any other lever applied to the lower end of the spindle, *d*), test the spring and see that it is in working order. The same lever can also be used to throw the catches or grips into action at any height in the pit when it is necessary to inspect or repair the sides of the pit or shaft; thus all strain is taken off the winding rope should the cage or hoist be at rest any length of time. In the diagram the invention is shown for a cage or hoist having only two guides (one on each side), but it is equally applicable to cages having three or four guides—whether of wood, iron or steel.

703. What apparatus or appliances are adopted for the prevention of overwinding?

Mr. Miles Settle has invented what he names an automatic invention to prevent overwinding, which can be applied to any winding engine. A longitudinal shaft, *e* (fig. 295), runs direct from the steam brake shaft, *f*, to the pit shaft, and is fixed at a given point above the landing of the cage. At the surface is a transverse shaft, *c* (fig. 296), and with this either cage ascending above the given point comes in contact, the longitudinal shaft, *e*, is turned round, this closes the valve, *a*, supplying steam to the steam engines, and simultaneously opens the valve, *b*, of the steam brake, and the engines are instantly stopped. A special feature in this invention is that should the engineman start his engines the wrong way the brake is applied and no damage done. The engineman can also apply the steam brake at any point he may desire, its action being automatic only in case of overwinding. After an overwind the engineman can put the arrangement ready for action again by simply adjusting a screw, without any assistance, and in less than one minute. In October 1888 the author saw the steam brake in operation at the Madeley Collieries, North Staffordshire, by the invitation of the inventor, when it was thoroughly tested at two pits, both with the cage empty and with a full tub in the cage, the steam brake in every test bringing the engines immediately to a stand. Permission was granted to the author to take charge of the engine, the empty cage being then in position to descend, but he reversed the gear of the engine and put steam on, determined to overwind if possible. The moment the cage came in contact with the transverse shaft, however, the engine was instantly brought to a stand, steam was then shut off, the gear of the engines reversed, and in less than one minute all was in order for winding again, thus proving all that the inventor claims.

A very useful appliance for the prevention of overwinding is the detaching hook. The following is a description of Walker's hook, which is the best that has come under the author's notice. It is made of the best forged iron, which must render it superior to any hook made of rolled plates, which are never so strong as

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hammered iron; then the strain on the lifting rope when an overwind takes place is not so great in Walker's hook as in hooks made of plates, because the area of the copper pins to be sheared is very much greater; also the load-pin and rope-pin which have to be lifted out of holes they are in, round sharp corners, makes the friction very severe in hooks made of plates.

The lifting rope is attached to the shackle, A (figs. 297 298, 299 and 300; the same letters refer to the same parts in all the figures), and the load to the connecting link, B. The supporting ring, C (through which the rope is constantly working), is a fixture in a baulk of timber, or iron girder, at the pit top. The hook consists of a pair of jaws, D D, working on a centre pin, E, in such a manner that the weight of the load has a tendency to open the upper limbs, which clip the strong centre pin of the shackle, A. The upper limbs are formed externally with jaw hooks, F F. The jaws are kept together and made to retain the shackle pin by means of the clamp, H, which is held in position by the pins, I I. In case of overwinding the jaw hooks (held together by the clamp) pass freely into the ring, C, but the projections, K K, of the clamp coming into contact with the bottom flange of the said ring, hold the clamp stationary while the jaws are being pulled through, the result being that the pins, I I, are sheared off, and the jaw hooks released from the restraint of the clamp. The internal diameter of the ring being the same as the width across the jaw hooks, F F, the rope remains secure until the jaw hooks reach the top of the ring, when, by the action of the weight of the load they are forced open, and so hook on to the top of the supporting ring, C, as shown in fig. 300, the rope passing harmlessly over the pulley. The recess, O, in the ring, C, is intended to meet an imaginary case that experiment shows to be almost impossible—namely, that if the engine is reversed after the pins, I I, are cut, and before the hooks reach the top of the ring, the jaws will then hook into the recess,

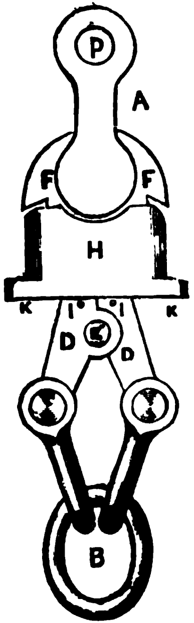


Fig. 297.

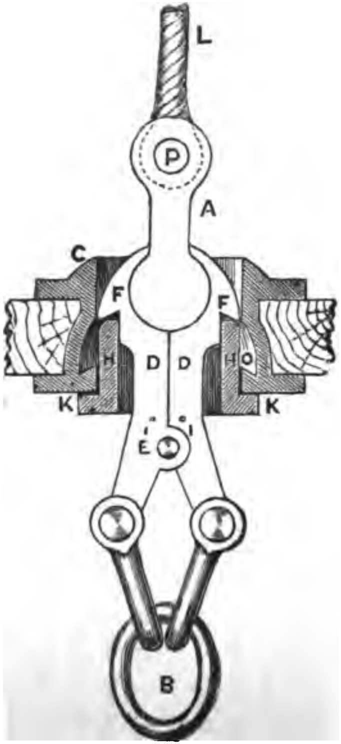


Fig. 299.

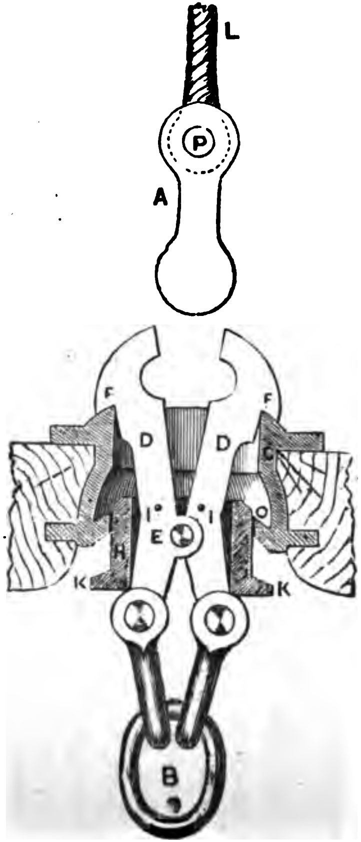


Fig. 300.

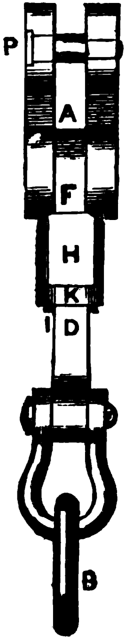


Fig. 298.

and the load remain suspended in perfect safety. It will be observed that the upper edge of the ring, C, is curved to match the sweep of the jaw hooks when opening. By this arrangement all shock is avoided.

704. Give a sketch and description of a good safety gate or fence for pit bottoms or insets in shafts to prevent workmen or tubs from falling down the shaft or sump.

Fig. 301 is a sketch of safety gates or fences for pit-bottoms, &c., where there are two cages running in the shaft. It is an arrangement of the author's own design, and has been adopted at several places where there are un-

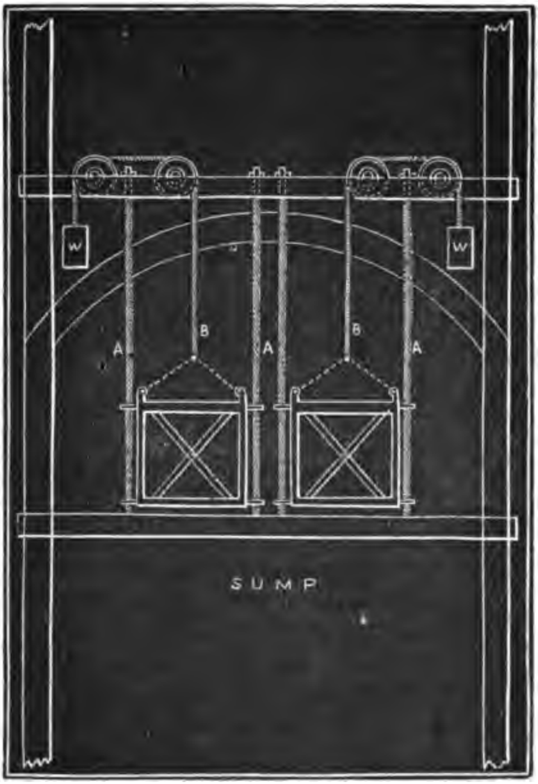


Fig. 301.

covered sumps. The gates are made of 1½ in. half-round steel, and in their making they may be either welded or riveted together. This size of steel makes a very strong, but at the same time very light gate, and only requires a small weight to balance it. Any old wire rope will do for guides, A, to hold the gates in position, the guides being secured at the lower ends to the sump sills, and the top ends to a cross-beam, on which the pulleys are fixed for the balance rope or chain, B, to work round. I have found ½ in. wire rope the most suitable for the balance rope. The weight, W, must be the exact weight of the gate, so that the gate will stay either at top or bottom or at any intermediate point.

705. Can you give a sketch of a safety fence or gate for pit-bottom where only one cage is at work in the shaft?

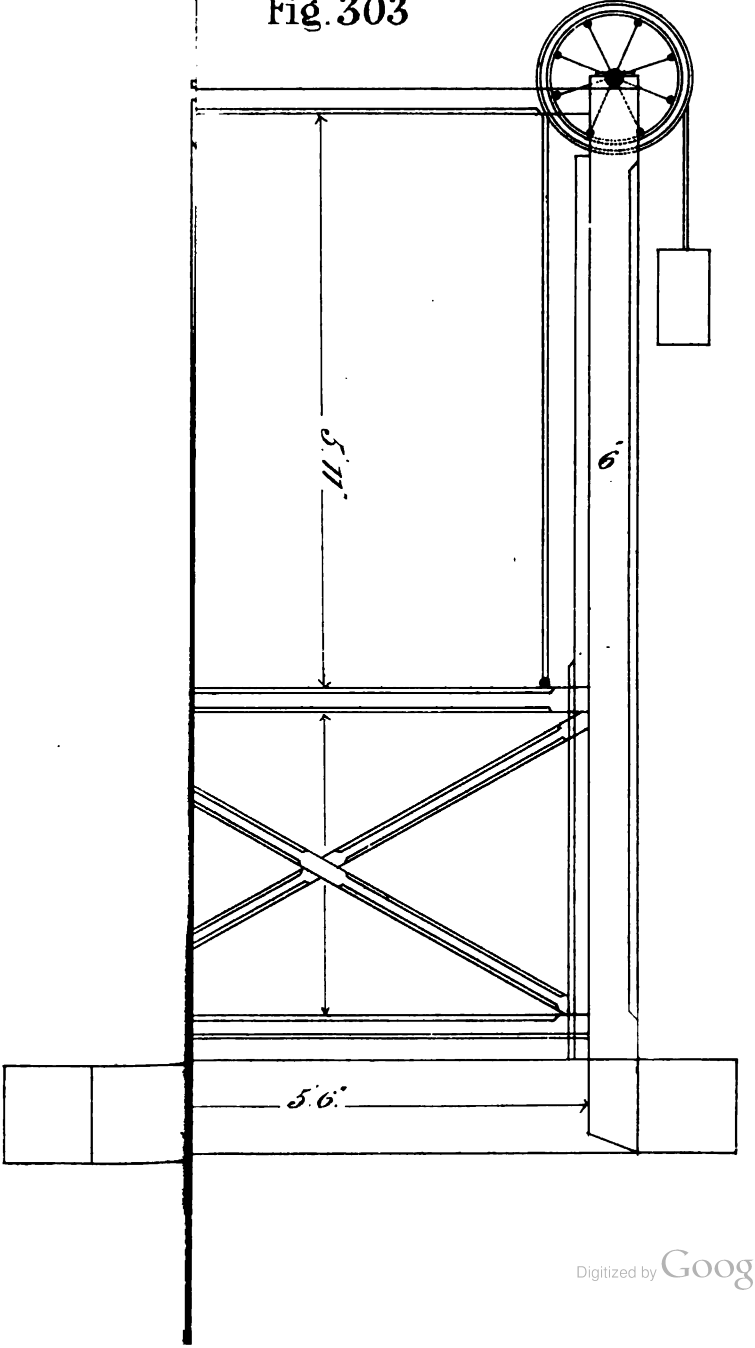
Yes; figs. 302 and 303 show side and end elevation, with dimensions. It will at once be seen that this is a simple and effective arrangement, and it has been at work in South Staffordshire for the last fifteen years. The gate is constructed from the designs of Mr. William Blakemore, mining engineer, formerly of the South Staffordshire district.

706. What means are adopted to counteract the strain on the capping of a winding rope when the engine taking the lift?

At some collieries a sliding iron box, packed with india-rubber buffers (similar to railway wagon buffer springs) is used. The attachment is made as a connection between the rope capping and the cage chains. This system has, however, the disadvantage that the rubber becomes hard and unyielding after a little use, so rendering frequent renewals necessary and on this account, though neat and compact, the method is costly. Another plan is to use a steel spring —similar to a railway wagon spring—which assumes the form of an inverted arch. In the middle of the spring and consequently at its deepest point, a strong iron belt is fixed by which the several layers of steel are held in

End Elevation

Fig. 303



position. To the top of this belt, and forged solid with it, is a shackle arrangement for receiving either the lower end of a disengaging hook, where such is used, or the capping of the rope itself. The spring ends are arranged for coupling to the cage chains. It will be seen from this description that the pull of the rope is directly over the centre of the load, and any shock at starting from the pit bottom is taken up by the elasticity of the spring. Another method, lighter and neater than the preceding one, and one that has given very good results, is effected by the use of a hollow volute spring. Fig. 304 fully explains the principle of this attachment. The benefits arising from the use of springs to counteract the shocks and jerks to which a winding rope is subject, are of no little importance; effecting, as they do, considerable saving in re-cappings, besides adding materially to the life of the winding rope.

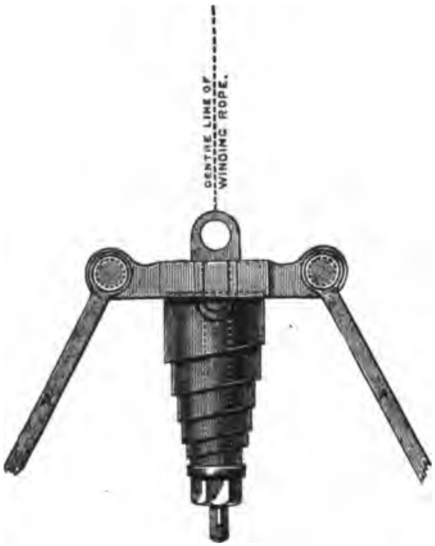


Fig. 304.

707. If steel rail conducting rods are decided on instead of wooden rods, how would you fit up the pit shaft?

I should proceed by walling or otherwise, fixing the horse-trees to the sides of the shaft in a manner similar to that adopted where wooden rods are used, except that if the cages have to stop at mouthings in the shaft, I would put the horse-trees next to the cage sides instead of the cage ends (see figs. 305, 306, 307, 308 and 309), in order to avoid the necessity of several sets of receiving rods. In fact, this plan acts just as well if carried out irrespective of shaft mouthings, and dispenses entirely with receiving rods at surface and shaft bottom. As the shoes attached to the cages almost make a circle round the rail head (see fig. 306) there need be no fear that the cage will get out of place, and consequently only one of its sides need be affixed to the conductors. When the horse-trees are in position, cast

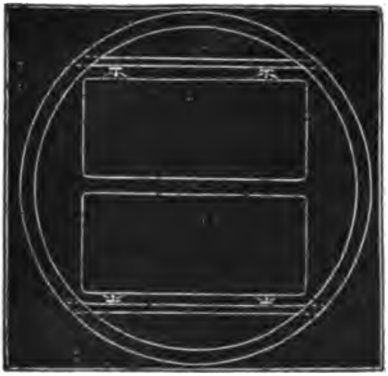


Fig. 305.

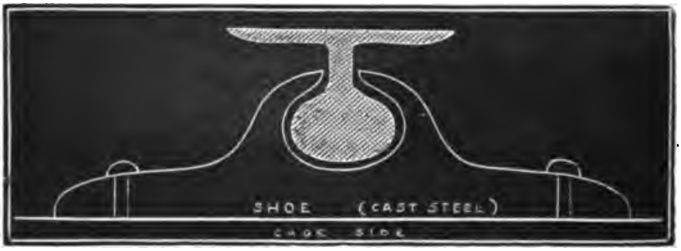


Fig. 306.

iron sleeper plates are bolted to them. These plates are ¾ in. thick except where they receive the rail (which is of the flat bottom single-headed type). Here they are thickened out to 1½ in., and have lugs cast on ½ in. deep to stay the rail sideways. The rails are also slightly notched at each side of the flat bottom so that the lugs carry the weight of the rail instead of the weight being on the bolts by which the rail is secured to the plate and horse-tree. Where two rails meet, the sleeper plate is 6 in. deep to allow a good bed and the means of fastening the end of each rail to the horse-trees, but for intermediate places, where the duty of the horse-tree is to steady the rail, the plates are made 4 in. deep. Steel rails, if properly fitted, are preferable to wood as conductors. (The author is indebted to Mr. John Hayes for the two last questions and drawings.)

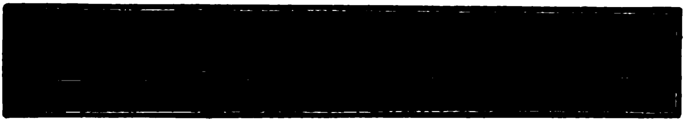


Fig. 307.

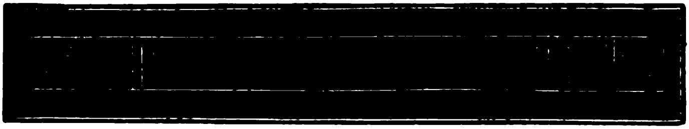


Fig. 308.

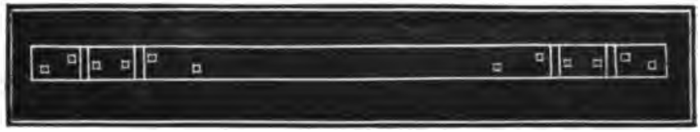


Fig. 309.

708. Describe the manner in which the cage is secured to the winding rope.

Cages are generally connected by four or six chains as the case may require; the chains are fastened to the cage by D-links, the pins of which pass through a hole punched at the top of each hanger; generally tightening screws are used for the purpose of equalising the lengths of the chains, as shown at AA (figs. 292 and 293).

709. What material is most suitable for rods or conductors—wood or iron rope?

In upcast shafts, round wire rods; but where the shaft is crooked and space is limited in the middle of the shaft, where the cages meet—under such circumstances I would put in wooden rods.

710. Suppose a pit with four wire conductors in which there is but little room; would you put a round rope or a flat one on, and why?

I would put a flat rope on, because there would be less vibration in the flat rope than in the round one.

711. If you were putting iron rods in your upcast shaft, how would you secure them at the bottom?

I would secure them as shown at fig. 15, by hanging weights at their bottom ends, BB. Immediately above the weights I would fix wooden bearers, through which the ends of the rods should pass for the purpose of keeping them steady, and so that they may not move out of their places. CC are wooden receiving rods for the purpose of guiding the cage through the framework at the mouthing or inset. The reason why iron rods should be secured with weights in an upcast shaft is that the temperature varies considerably in upcast shafts, and causes great expansion and contraction in the rods; when rods are fastened by screws they get slacker as the temperature of the shaft increases; and I have known instances where, the furnaces having been damped out for repairs, the rods have contracted and have broken the timber to which they were fastened in the headgear. This difficulty, however, is overcome by adopting the weights, which rise and fall with the expansion and contraction. In a downcast shaft I would recommend iron rods to be fastened as seen at A (fig. 310). In this case the ends of the rods pass through the baulks as before, and are fastened at the under side by nuts and screws.

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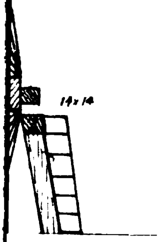


Fig. 316

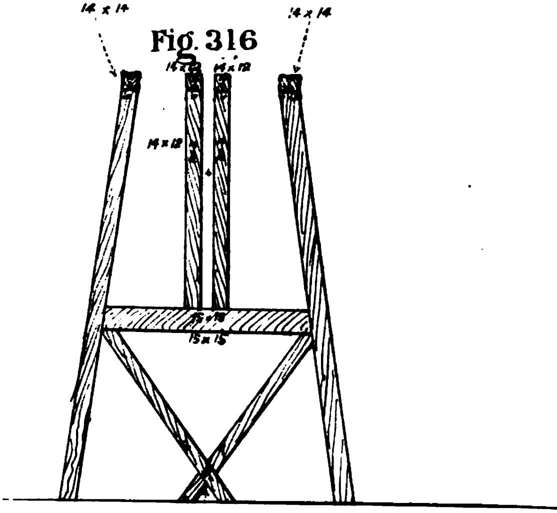
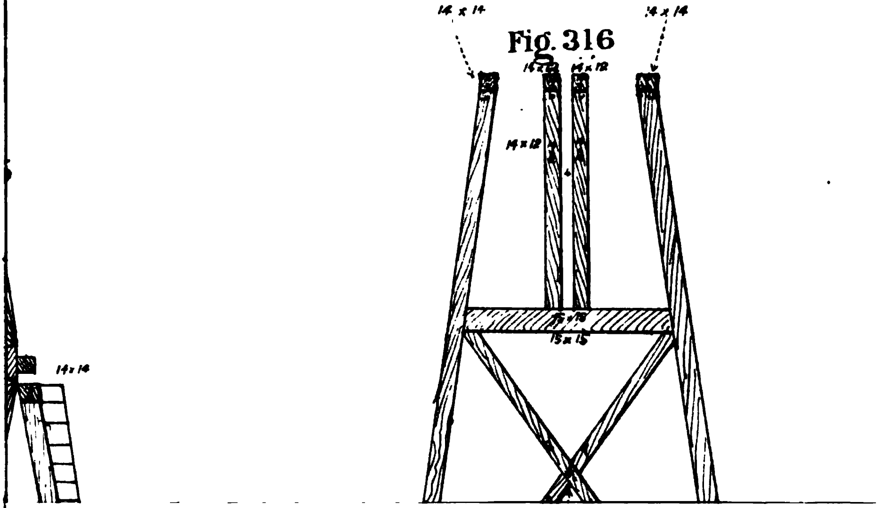


Fig. 316



of winding shafts at collieries there is an advantage in having them as large as practicable, to lessen the friction, as well as to avoid the injury to ropes which is occasioned in bending over small pulleys.

716. If your winding drum and pulley wheels are only 7 ft. diameter each, and round ropes are in use, how many strands would you have to your rope, and how many wires in each strand?

I would have a rope 1⅛ in. diameter, made of six strands, each strand containing nineteen wires. This would be termed a compound rope.

717. In laying out a new colliery plant, would you put up your gearing for round or flat ropes, and why?

I should put up gearing for round ropes—first, because flat ropes are very expensive; secondly they are of enormous weight—twice as heavy as a round rope to do the same work; thirdly, they are very uncertain in their manufacture.

718. Which is the best material for winding ropes—iron or steel?

I consider steel the best. To perform the same work iron ropes must be much heavier than steel, and would have a higher total cost; larger drums and pulleys would consequently be necessary for the rope to coil over, and the load would be considerably added to on account of increased weight of rope.

719. Can you give a rule for finding the breaking strain and safe working load for ropes?

The strength of a rope varies in proportion to the material contained in its section. The section being a circle. the strength will vary as the square of the diameter of the section. The breaking strain of a hemp rope 1 in. in diameter is about 2½ tons; the breaking strain of an iron wire rope 1 in. in diameter is about 15 tons; the breaking strain of a steel wire rope 1 in. in diameter is about 25 tons. The proof strength of a rope is taken at three times the working load, and the breaking strain at five times the working load for round ropes, and nine times the working load for flat ropes.

To find the breaking strain of a round rope:—Let c = circumference in inches. Then $c^2 \times \cdot 25$ = breaking strain for hemp rope; $c^2 \times 1\cdot 5$ = breaking strain for iron wire rope, and $c^2 \times 2\cdot 5$ = breaking strain for steel rope. The working load being one-fifth of the breaking strain, the rule to find the working load is: Square the diameter in inches, and multiply—for hemp by 0·5; for iron by ·3; for steel by ·5. To find the breaking strain multiply the result by 5, the answer being in tons of 2,000 lb.

Examples.—(1.) What is the working load and breaking strain of a 2 in. hemp rope? $2^2 = 4 \times \cdot 5 = 2\cdot 0$, working load, and $2\cdot 0 \times 5 = 10$ tons, the breaking strain. (2.) What is the working load and breaking strain of a $1\frac{3}{4}$ in. iron wire rope? $1\cdot 75^2 = 3\cdot 0625 \times 3 = 9\cdot 1875$ working load, and $5 \times 9\cdot 1875 = 45\cdot 9375$ tons, the breaking strain. (3.) What is the working load and breaking strain of a $1\frac{1}{4}$ in. steel wire rope? $1\cdot 25^2 = 1\cdot 5625 \times 5 = 7\cdot 8125$, the working load, and $7\cdot 8125 \times 5 = 39\cdot 0625$ tons, the breaking strain.

To find the weight of ropes:—

c^2 = weight in cwts. of 450 fathoms for hemp ropes,
c^2 = „ 128 „ wire „

For flat ropes, the extra weight per fathom, as compared with round ropes of the same strength, is as 5 to 4.

720. Can you give a rule for finding the breaking strain and working load of chains?

The strength of a chain varies according to the quality of the material of which it is made—that is, chains made from best iron or steel will have a greater tensile strength than those made from common iron. Many rules have been given for finding the strength of chains, but the three following are, perhaps, the most simple:—First rule: Square the diameter of the chain in sixteenths of an inch, and divide by ten for the breaking strain in tons; the breaking strain is four times the safe load. Second rule: Square the number of eighths of an inch in the diameter of the iron out of which the chain is made and strike off the last figure as a decimal. Example: In an inch chain there are eight eighths of an inch ; thus 8 × 8 = 64, and strike off the last figure = 6·4 tons, the greatest safe load. Again, for ½ in. chain, 4 × 4 = 16 ; strike off the last figure as before, we get 1·6 tons the safe load, the breaking strain being four times the safe load. Third rule : The following is a formula generally used to find the strength of chains :—Let W = breaking strain in tons ; D, diameter in sixteenths of an inch. Then $W = \frac{D^2}{9}$; ∵ $D = \sqrt{9W}$.

721. Can you give a table of the sizes, weights, lengths, and breaking strains of iron wire ?

The following is a table of sizes, weights, lengths and breaking strains of iron wire, issued by the Iron and Steel Wire Manufacturers' Association, on March 1st, 1885 :—

Size of Wire Gauge.	Diameter.		Sectional Area in Square Inches.	Weight.		Length of Hundredweight.	Breaking Strains.		Size of Wire Gauge.
				100 Yards.	Mile.		Annealed.	Bright.	
	In.	Mm.		Lb.	Lb.	Yards.	Lb.	Lb.	
7—0	·500	12·7	·1963	193·4	3,404	58	10,470	15,700	7—0
6—0	·464	11·8	·1691	166·5	2,930	67	9,017	13,525	6—0
5—0	·432	11	·1466	144·4	2,541	78	7,814	11,725	5—0
4—0	·400	10·2	·1257	123·8	2,179	91	6,702	10,052	4—0
3—0	·372	9·4	·1087	107·1	1,885	105	5,796	8,694	3—0
2—0	·348	8·8	·0951	93·7	1,649	120	5,072	7,608	2—0
1—0	·324	8·2	·0824	81·2	1,429	138	4,397	6,595	1—0
1	·300	7·6	·0707	69·6	1,225	161	3,770	5,655	1
2	·276	7	·0598	58·9	1,037	190	3,190	4,785	2
3	·252	6·4	·0499	49·1	864	228	2,660	3,990	3
4	·232	5·9	·0423	41·6	732	269	2,254	3,381	4
5	·212	5·4	·0353	34·8	612	322	1,883	2,824	5
6	·192	4·9	·0290	28·5	502	393	1,544	2,316	6
7	·176	4·5	·0243	24	422	467	1,298	1,946	7
8	·160	4·1	·0201	19·8	348	566	1,072	1,608	8
9	·144	3·7	·0163	16	282	700	869	1,303	9
10	·128	3·3	·0129	12·7	223	882	687	1,030	10
11	·116	3	·0106	10·4	183	1,077	564	845	11
12	·104	2·6	·0085	8·4	148	1,333	454	680	12
13	·092	2·3	·0066	6·5	114	1,723	355	532	13
14	·080	2	·0050	5	88	2,240	268	402	14
15	·072	1·8	·0041	4	70	2,800	218	326	15
16	·064	1·6	·0032	3·2	56	3,500	172	257	16
17	·056	1·4	·0025	2·4	42	4,667	131	197	17
18	·048	1·2	·0018	1·8	32	6,232	97	145	18
19	·040	1	·0013	1·2	21	9,333	67	100	19
20	·036	0·9	·0010	1	18	11,200	55	82	20

722. Can you give a short table of the sizes and proof strains of chains?

The following is a short table of the sizes and proof strains of chains:—

TABLE OF PROOF STRAINS.

Size of iron in chain. In.	Proof strain. Tons.	Size of iron in chain. In.	Proof strain. Tons.
$\frac{5}{16}$	$1\frac{1}{8}$	$\frac{13}{16}$	$7\frac{7}{8}$
$\frac{3}{8}$	$1\frac{5}{8}$	$\frac{7}{8}$	$9\frac{1}{8}$
$\frac{7}{16}$	$2\frac{1}{4}$	$\frac{15}{16}$	$10\frac{1}{2}$
$\frac{1}{2}$	3	1	12
$\frac{9}{16}$	$3\frac{3}{4}$	$1\frac{1}{8}$	$15\frac{1}{4}$
$\frac{5}{8}$	$4\frac{5}{8}$	$1\frac{1}{4}$	$18\frac{3}{4}$
$\frac{11}{16}$	$5\frac{5}{8}$	$1\frac{3}{8}$	$22\frac{5}{8}$
$\frac{3}{4}$	$6\frac{3}{4}$	$1\frac{1}{2}$	27

723. Would you have your catches at the top of the pit for the cages to rest upon, of wrought or cast iron?

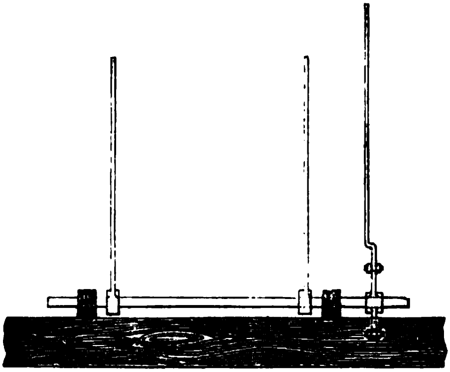


Fig. 317.

I would use wrought iron. Many accidents have occurred where cast iron catches have been in use, through the legs of the catches breaking off when the cage, in passing through the framework at the top, happened to come in contact with them. For a plain and durable set to catches, with levers, &c., see figs. 317 and 318.

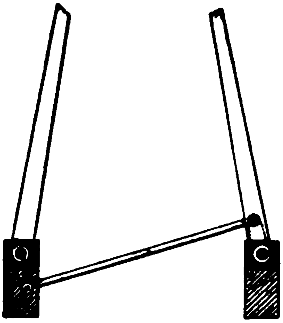
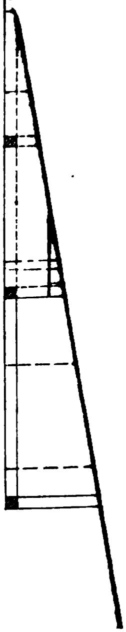
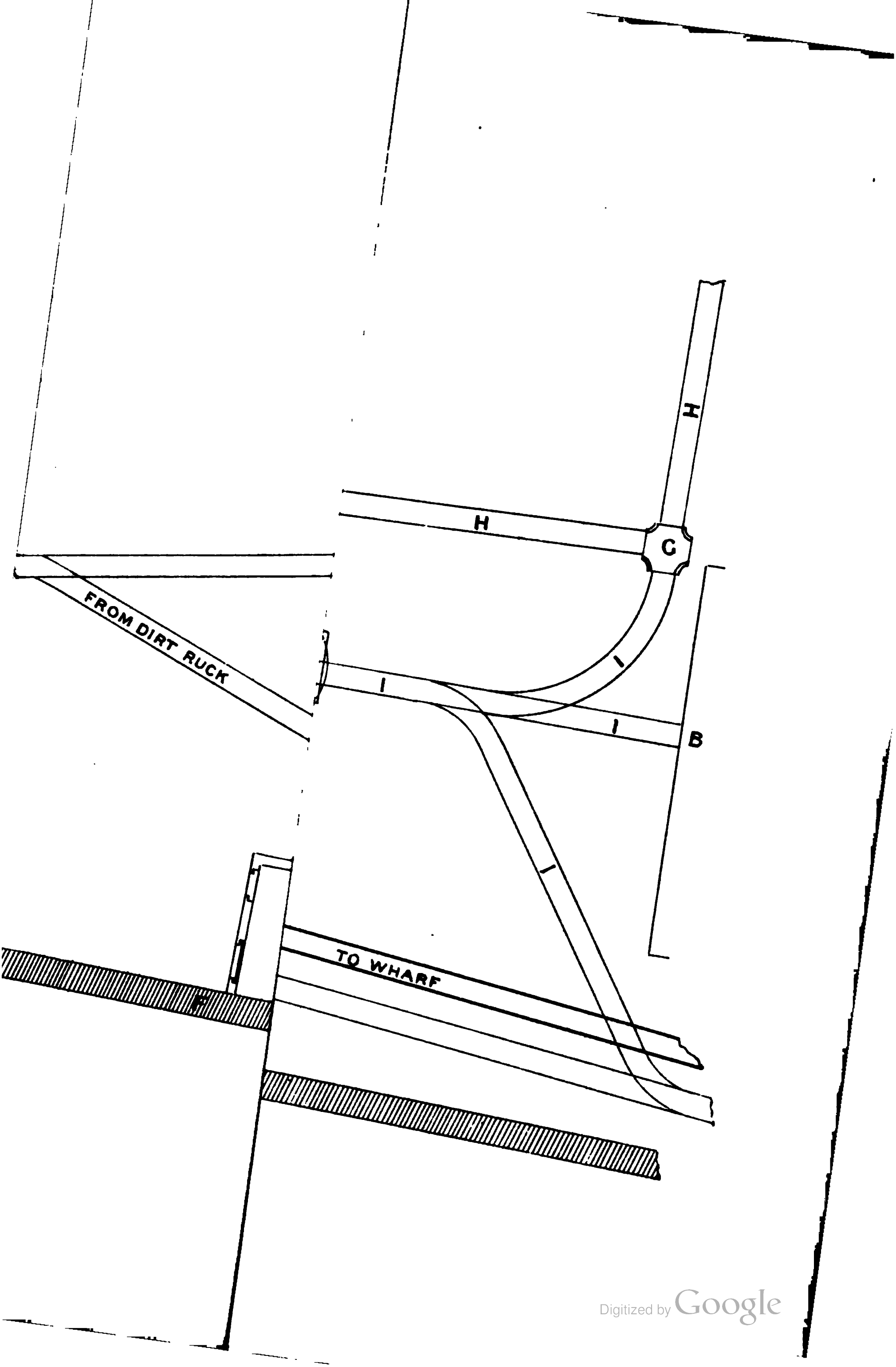


Fig. 318.

724. Produce a sketch of pit-bank arrangements for an output of 1,000 tons per day, where all the banking and screening are carried on on staging, as is usually adopted in Lancashire, showing the lines of tram rails and coal tipplers; also show the railway metals and coal trucks in position below the staging.

I would lay out a pit-bank or brow, as shown in fig. 319, which, it will be seen, is supported on a huge wooden framework, such as is usually adopted in Lancashire. A A is the pit or opening in the staging for the cages to work through; B B are sets of tram rails for conveying the coal boxes from the cages over the check-weighing machine, thence to the coal tipplers, C C; the tippler in the centre, marked D, is reversed for burgie and dirt; E E are iron turn-plates for turning the coal-boxes at the front of each tippler; F F are lines of tram rails for the empty coal-boxes to run along to the iron landing plates at the back of the pit, marked G; the check-weighing machine and cabin for weighing each collier's coals is marked H H; the coal wagons or trucks, marked I I, are shown in their position underneath the tipplers and staging while being loaded




H
H
G
FROM DIRT RUCK
I
I
I
I
B
TO WHARF
F

Gr

from the screens, the dotted lines running through them showing the railway metals.

725. Produce a sketch of pit-bank arrangements where the banking and screening are carried on on the ground-floor, as is usual in the Midland counties.

Fig. 320 is a plan of the usual pit-bank arrangements in the Midland counties. A A are the two pits, showing the two cages—one with its end, the other with its side towards the engine, to suit the pit-bottom arrangements; B is the engine-house; C is the checkweighing machine and house; D is the banksmen's cabin; E is the lamp house; F is the screen wall; G are the turning plates. The heavy lines (H) are lines of tram rails for the loaded trams to pass over, and the thin lines (I) are lines of tram rails for the empty trams to pass over. It will be seen from the sketch that the lines of tram rails and the checkweighing machine are so arranged that the loaded and empty trams do not come in contact with each other—that is, when the trams are emptied they pass in opposite directions to the loaded ones, and are run in the cages from the opposite sides of the pits to those from which the loaded trams are taken.

726. Give a short description of a good checkweighing machine for pit-banks, to weigh the workmen's tubs.

Fig. 321 shows the foundation required for a Pooley's patent turntable weighing machine on pit-bank, and the whole of the details for putting in the foundation and framework are shown in figs. 322 and 323. This is one of the most accurate and simple weighing machines I know of. It consists of double steelyards; one bar is marked to 15 cwt. in divisions of 1 cwt., and the weight on this bar is fixed at the average weight of the loaded tubs in hundredweights; there is also fixed on this bar another weight for tare of empty tubs; the second bar is marked to 5 cwt. in divisions of 14 lb., and can be moved forward and backward at will by the weighman.

A self-indicating machine for weighing the tubs at collieries has been recently introduced by Messrs. Hodgson and Stead, of Salford, which dispenses entirely with all springs, toothed wheels, racks and pinions and loose weights. (fig. 324). The construction is exceedingly simple, and the machine may be described as an ordinary steel-yard machine which automatically shows the weight of the article placed on it. A, B, C are weights as on an ordinary steel-yard, A being the tare weight, B a weight to be fixed at the point representing the lightest net load, and C the balance or adjusting weight. The net weight is shown on the quadrant D by a pointer, which is actuated by the rising of the steelyard, the figures being a continuation of the weight shown by B. The illustration shows an arrange-

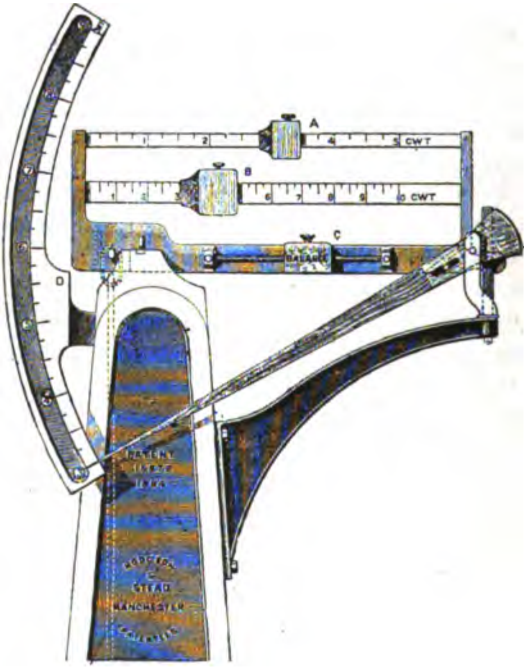


Fig. 324.

ment for a difference of 6 cwt. between the lightest and heaviest loads, but any difference can be allowed for, whilst the figures are movable and adaptable to any weights. The machine does not easily get out of order, is very rapid in its action and is of but moderate cost. This new machine is rapidly finding favour at the leading collieries.

727. Can you give a diagram, showing the method of calculating the distance at which the hind or back leg of the pit-frame should be placed in relation to the front ones?

Mr. Herbert W. Hughes gives the following rule for calculating the distance (fig. 325). B C = height of pulleys from ground = 40 ft. A B = distance of centre of shaft from centre of drum = 30 yards = 90 ft. Then tan. of $\angle$ C A B = $\frac{\text{B C}}{\text{A B}} = \frac{40}{90} = \cdot\dot{4}$ ∵ $\angle$ C A B = 23 degs. 57 min., and $\angle$ A C B = 66 degs. 3 min. That is, the ropes are inclined to each other 66 degs. 3 min. (passing down the pit and to the drum). Then, in the case of winding, the power used and the weight lifted are equal, and act in contrary directions, the power acting in the direction C A and the weight in the direction C B. As these are equal, the direction in which the resultant acts

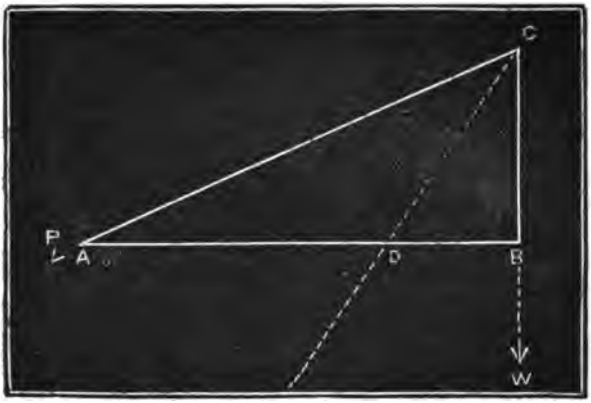


Fig. 325.

will be in a line bisecting the angle A C B—that is, in a line inclined at 33 degs. 1·5 min. to the rope passing down the shaft C B. This line is shown at C D. The distance B D may be found thus:—D B = tan. 33 degs. 1 min. × C B = ·6498 × 40 = 25·99 ft. (say 30 feet). If the back stays of the frame be placed so that they coincide with C D, then the structure will be capable of standing all strains due to ordinary winding, but should some unexpected accident happen, in which the power becomes greater than the weight (for example, overwinding where the cage is drawn violently against the head-gear), the pit-frames may be pulled over.

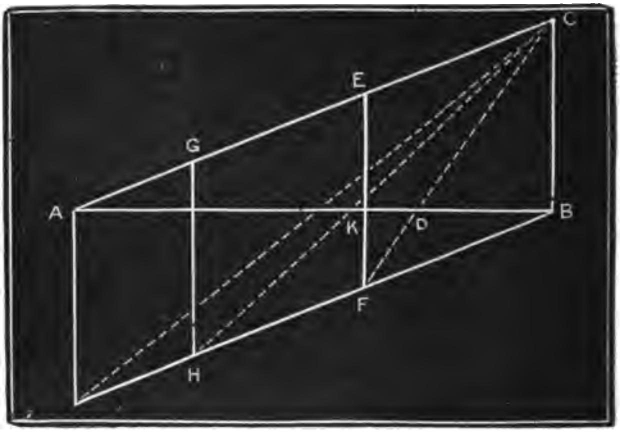


Fig. 326.

To allow for this, it will be better to increase the distance D B above the theoretical length found. If D B be increased to 40 ft., then a wide margin of safety will be given without damaging the stability of the structure. This increase of the distance D B to 40 ft. will allow the power to increase to twice the weight without causing the frames to overturn. The preceding has been worked out by the principle of the parallelogram of forces. It may also be done graphically as in the diagram, fig. 326. Let A B = distance between centre of drum and centre of pit-shaft, and C B the height of pit-frames as before, C A the direction in which power is acting, and C B the direction in which weight is acting. If power and weight be equal, lay off along C A any length C E; and lay off the same length along C B; from E draw a line E F parallel to C B, and from B draw a line B F parallel to C A, and cutting E F at F. The direction and magnitude of the resultant force will be given by the line C F, the diagonal of the parallelogram; the point D, where it cuts the ground line A B, will be the point at which the back stay of frame is to meet the ground; and, if the diagram be drawn to scale, the distance D B may be measured, and will be found to be 30 ft. as calculated. If it is intended to allow for casualties, when the power may become twice the weight, all that need be done is to log off on C A a length of C G equal to twice that laid off on C B, and construct the parallelogram as before. The point K, where the diagonal C H cuts the line A B, will give the point from which to measure the length K B, which will determine the width of base of pit frames. Of course, in an actual case of overwinding, the weight of the frames will reduce the likelihood of their being pulled over, and will add to their stability. Indeed, it is very probable, unless a detaching hook be used, that either the headgear would be smashed or the rope broken.

728. Can you give a good sketch of a tippler for side tipping?

Yes. Figs. 327 and 328 are views of a good side tippler. The side rim, A, of the tippler is grooved to allow it to rest on four small pulleys, B, cone-shaped at their outer edges to fit in the groove. This class of tippler is well adapted for discharging the coals with little breakage on the screen bars; the coals are also well placed for separation.

729. What class of screen bars do you recommend where the bars have to be changed to meet the requirements of trade?

Both round and flat wrought iron bars are objectionable. Malleable and cast iron bars are coming more and more

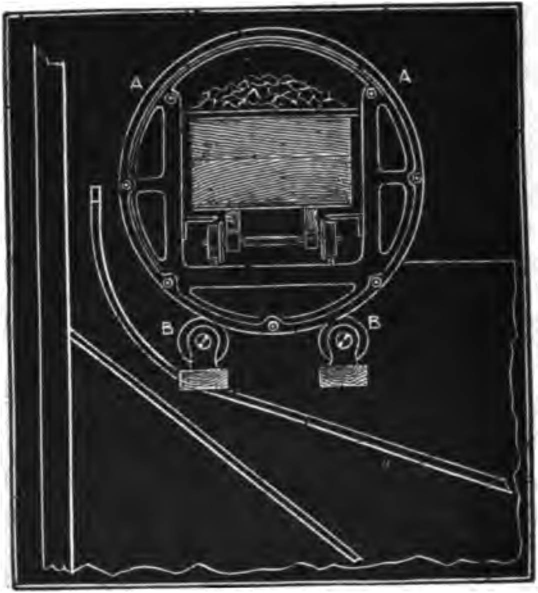


Fig. 327.

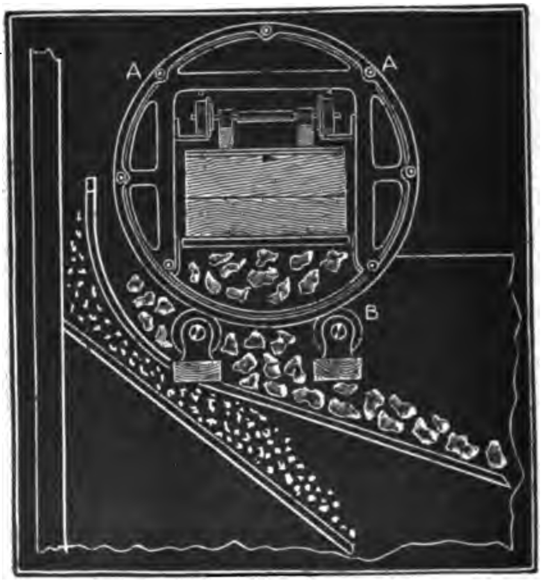


Fig. 328.

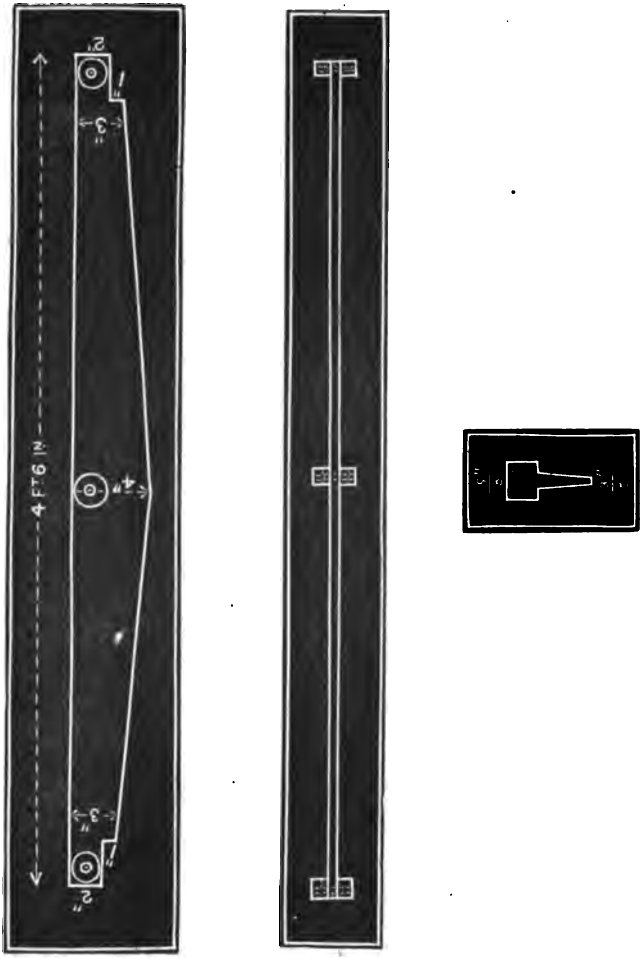
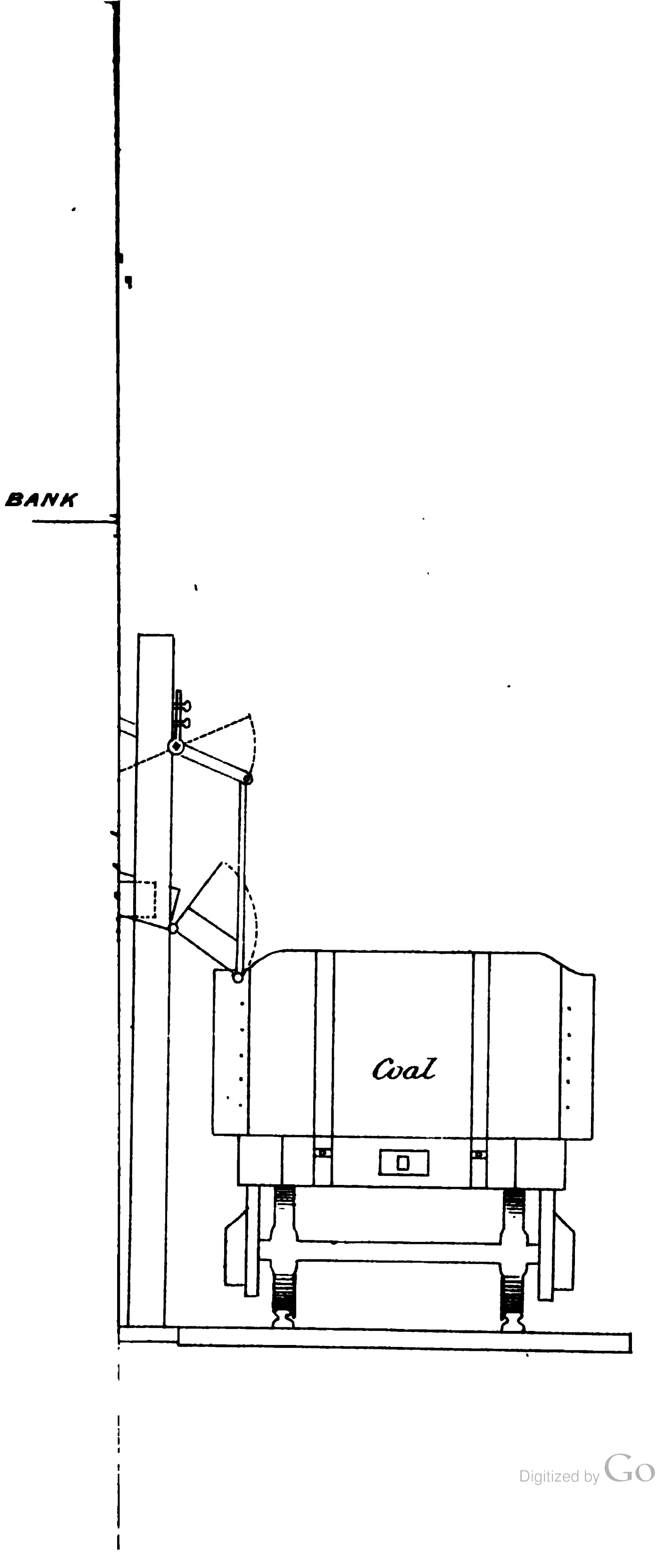


Fig. 229.

into use; they are generally 4 ft. 6 in. long, made with round nogs at each end and at the centre; there is a ½ in. hole through each nog, allowing five or six or any number of bars to be firmly riveted together, thus forming a uniform mesh over the whole surface of the screen. The riveting together also greatly facilitates the removal of the bars when a larger or smaller mesh is required. The bars are thinner at their lower edges than at the surface edges, to avoid clogging. (See fig. 329.)

730. Can you supply a sketch and give particulars of an inexpensive screen suitable for ordinary use at collieries?

This will be found at fig. 330, which represents the side elevation of a screen, three of which have been erected by the author at the Aldridge Colliery. As shown, this screen is intended to supply three qualities—viz., large coal, nuts and fine slack. Anyone practically acquainted with the coal market knows that one of the most persistent demands is that coal shall be "clean," and nothing causes more difficulty to the salesman than badly-screened coal. A very general cause of the latter is that the screen is so fixed that the gradient is a steep one and the contents of the tubs are literally "shot" over the bars and into the trucks, carrying slack and large indiscriminately into the best coal. The screen in question has been specially designed to meet this difficulty, and is so "flat" that all the coal has to be raked down, which not only effectually liberates the slack, but offers every opportunity for picking and chipping, so that nothing but gross carelessness will interfere with the quality of the best coal. Further to aid this, a back tippler is used, tipping towards the banksman, the result of which is that the contents of the tub have not so far to fall, the coal is not broken, and it is not dashed on to the screen bars with such force as to send it along before it can be properly dealt with. From 150 to 200 tons per day can be passed over each screen with one man and two lads to attend to it. I would mention that this tippler was supplied by Messrs. J. Wood and Co., Wigan.


BANK
Coal

731. Have you met with a more complicated screen intended to deal with large quantities, and to separate into a greater variety of qualities than the one just described?

The "Shaker" screen, designed by Mr. Edward Lyall, manager of the Essington Farm Colliery, near Bloxwich, divides the coal into four sizes, and does it so rapidly that one screen will deal with a large output. The arrangement is compact, affording facilities for picking out impurities or different qualities of coal. The first "Shaker" screen was designed for the Walsall Wood Colliery, near Walsall, one of the deepest pits in South Staffordshire, and although only an experiment and in many respects incomplete, it has worked successfully, materially reducing the cost of banking, improving the quality and enabling the output to be

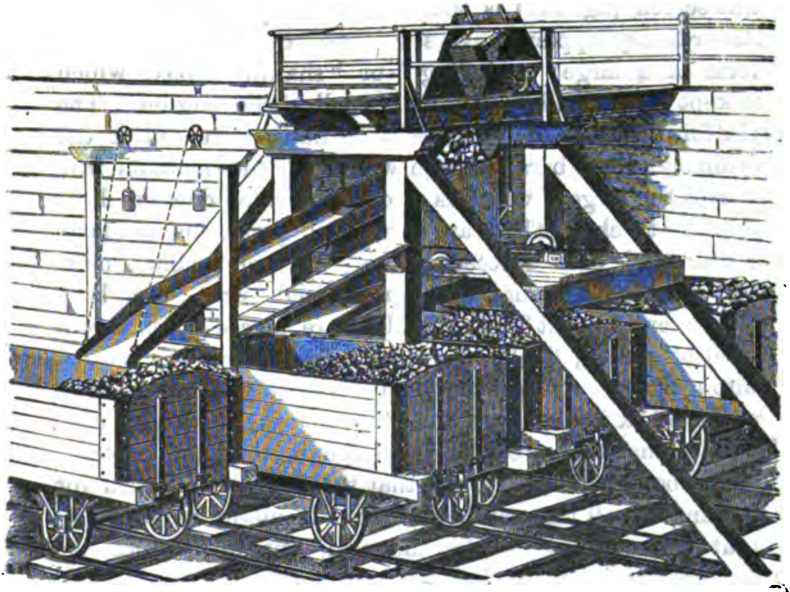


Fig 331.

increased. A second improved screen is now at work at the same colliery, two more at the Cannock Chase Colliery Company's No. 3 pit, one at West Cannock Colliery, and one at Aldridge Colliery, all of which are said to give satisfaction. The apparatus is simple, and may be constructed at the colliery from the drawings which Mr. Lyall supplies with the licence to use his patent, or the machines can be supplied complete. The principle of this screen (fig. 331) is that of the "threshing machine." An ordinary tippler delivers the coal on the upper platform of a large "swinging" or "shaking" box, which is kept in motion laterally by a small steam engine. The platform consists of a lattice wire netting in lieu of the ordinary screen bars, through which all the contents fall, except the largest, which is at once delivered down a shoot into the trucks. There are three such platforms similarly constructed, each succeeding one being of smaller mesh, and each delivering its own special size through a convenient "spout," at which lads are placed to pick out inferior pieces; finally, the slack falls through the bottom into a truck. As each platform slants only about 1 in 4, and the box is kept constantly in motion, it will at once be seen that the screening is thorough, that the contents of the box travel easily, and that the facilities afforded for picking are all that can be desired. It might be supposed that the shaking breaks the coal, but in practice the breakage is not more than in an ordinary screen.

732. In opening a new colliery where it is necessary to erect dwellings to accommodate the workmen, give sketch of a plan showing the size and form of a good, cheap and substantial building.

Where it is allowed by the owner of the estate, as colliers do not as a rule like to pay high rents, miners' dwellings are generally built in rows, as seen in figs. 332, 333, 334; the form and size and full details, as given on plan, will be found suitable and convenient. In some cases estate owners will not allow rows of dwellings to be built

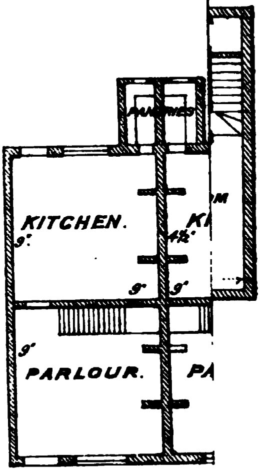
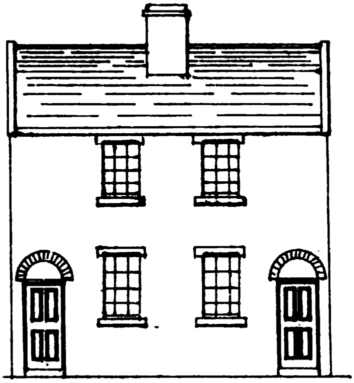


Fig. 337.



FRONT ELEVATION.

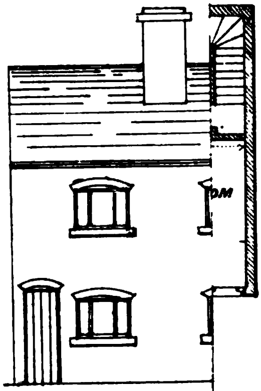
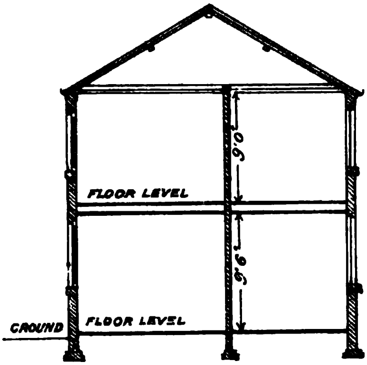


Fig. 338.



TRANSVERSE SECTION

REFEREN

The divis

The plot

only permitting blocks of twos, at suitable distances from each other; when this is the case the dimensions, form, &c. are as shown at figs. 335, 336, 337, 338.

733. How is the building of engine-houses, engine-pillars, workmen's cottages, &c., contracted for?

Usually, the contract is taken at so much per superficial yard to a thickness of 18 in.; beyond that, as in engine-pillars, for example, it is paid so much per cubic yard. Generally, the fixed price among bricklayers is 9d. per superficial yard for 9 in. work; in building engine-pillars and other solid massive brickwork, the fixed price is 2s. 6d. per cubic yard, no hollow spaces being measured in. The price generally paid for slating roofs is from 4d. to 6d. per superficial yard, according to circumstances.

CHAPTER XII.

MATHEMATICS.

734. What is meant by mathematics?

Mathematics is a system of reasoning; the science in which known relations between magnitudes are subjected to certain processes which enable other relations to be deduced. Mathematical principles are deduced from axioms with the help of certain definitions belonging to pure mathematics, and those which have been deduced with the help of pure mathematics from certain simple physical laws.

735. What is meant by geometry and trignonometry?

Geometry and trigonometry establish the relations of the lengths of straight and curved lines, the areas of plane and curved surfaces, and the volumes of mathematical figures; the arithmetical adoption of these relations is called mensuration.

736. Who was the father of modern geometry?

The geometry of the ancient philosophers has been transmitted to us by Euclid. Many of Euclid's demonstrations are set aside and regarded as axiomatic, others are much more easily effected by algebra and trigonometric methods.

737. Are the different branches of mathematics of service in practical mining?

Yes; mensuration is necessary in measuring various constructions, and in tunnelling, in the sinking of shafts, &c.; geometry and trigonometry in surveying. The office work cannot be carried out without a good knowledge of common arithmetic.

738. Give an explanation of the signs, &c., made use of in general arithmetic.

The following is an explanation of the signs, &c., used in arithmetic:—

$=$ signifies equality, as 9 added to 7 is equal to 16.

$+$ „ plus, or more, as 9 added to 7 is equal to 16.

$-$ „ minus, or less, as 6 from 8 is equal to 2.

$\times$ „ multiply by, as 7×5 is equal to 35, or $a \times b \times c = a, b, c$.

$\div$ „ division, as 64 divided by 8 is equal to 8; or quantities that are to be divided by other quantities may be represented thus:—$\frac{16}{4}$ which means that 16 is to be divided by 4; also $\frac{a \times b}{a - c}$ denotes that the sum of a and b is to be divided by a minus c.

: :: : thus—$1 : 2 :: 3 : 6$—are called proportionals, and read as follows:—As 1 is to 2 so is 3 to 6.

$\surd$ signifies or marks the square root, as $\sqrt{16}$ is equal to 4, because $4 \times 4 = 16$.

$\sqrt[3]{\ }$ signifies or marks the cube root or third power, as $\sqrt[3]{125}$ equals 5, that is $5 \times 5 \times 5 = 125$. The index $\frac{1}{3}$ placed over a, thus $a^{\frac{1}{3}}$ denotes the cube root of a.

8^2 „ that 8 is to be squared, as $8^2 = 64$.

8^3 „ that 8 is to be cubed, as $8^3 = 512$.

$\overline{\quad}$ the bar or vinculum, denotes that two or more are to be taken together, as $4 \times \overline{8 + 2} = 40$, and $\sqrt{6^2 - \overline{3^2}} = 5$ signifies that the 3 squared subtracted from 6 squared, and the square root extracted is equal to 5. The same may be expressed by the parentheses ( ), as $(4 + 6) \times 5 = 50$.

$\frac{40}{8}$ denotes that 40 is to be divided by 8; this character is common in vulgar fractions. This sign may be used in conjunction with the bar or vinculum, thus, $\frac{5-2}{3 \times 2} = \frac{3}{6} = \cdot 5$.

Degrees are expressed by writing (°) over them, as 25° for 25 degrees.

Minutes are marked by an accent (′).

Seconds thus (″), &c. Thus, 25° 30′ 4″ 34‴ is read 25 degrees 30 minutes 4 seconds and 34 thirds.

Decimal fractions are so called from the Latin, *decem* (ten), which denotes the nature of its numbers, representing the parts of an integral quantity divided into a tenfold proportion.

In decimal fractions, the integer or whole number, as an acre, a yard, a pound, a gallon, &c., is supposed to be divided into ten equal parts, called tenths; these tenths into ten equal parts called hundredths, and so on without end, so that the denomination of a decimal is always known to consist of a unit with as many cyphers as the numerator has places; it is, therefore, never expressed, being understood to be 10, 100, 1,000, 10,000, &c., according as the numerator consists of one, two, three, four, five or more figures. Thus, in decimal fractions, instead of $\frac{3}{10}$, $\frac{25}{100}$, $\frac{312}{1000}$, the numbers are written with a full point before them, called the decimal point, thus ·3, ·25, ·312. If a unit of any kind, as an acre, a yard, a gallon, &c., be divided into parts, the decimal represents as many of those parts as the decimal figures express, thus ·5 means five of those parts, or five-tenths. If the decimal consist of two figures, the unit will be understood to be divided into a hundred equal parts, of which the decimal represents as many as the figures express, thus ·75 means seventy-five of those parts, or seventy-five hundredths; if the decimal consists of three figures the unit would be a thousand, thus ·725 is seven hundred and twenty-five of those parts; or if the decimal is ·0725, unity would be divided into 10,000 equal parts, and so on.

739. Give a rule to find the decimal that would be equivalent to any fractional part of a foot—that is, the decimal to equal fractional parts of a foot, say 1 in., 2 in., and so on.

If, for example, one piece of timber measured 10 ft. 6 in. and another piece measured 10 ft. 3 in., and a third 10 ft. 9 in., I would get the decimals equivalent in fractional parts of a foot to the 6, 3, and 9, thus:—Add cyphers to the fractions and divide by 12; this will give the decimals.

Example:— $\frac{3{\cdot}00 \text{ in.}}{12} = {\cdot}25$; again, for the 6 in. $\frac{6{\cdot}0 \text{ in.}}{12} = {\cdot}5$; and the same for the 9 in. $\frac{9{\cdot}00 \text{ in.}}{12} = {\cdot}75$; and so on for any fractional part.

740. Produce an accurate table of fractional parts of an inch with corresponding decimals.

The following is such a table:—

TABLE OF THE FRACTIONAL PARTS OF AN INCH WITH CORRESPONDING DECIMALS.

Decimals.	Fractions.				Decimals.	Fractions.			
·0078125 =				1/128	·2578125 =	1/4	—	—	1/128
·0156250			1/64	—	·2656250	1/4	—	1/64	—
·0234375			1/64	1/128	·2734375	1/4	—	1/64	1/128
·0312500		1/32	—	—	·2812500	1/4	1/32	—	—
·0390625		1/32	—	1/128	·2890625	1/4	1/32	—	1/128
·0468750		1/32	1/64	—	·2968750	1/4	1/32	1/64	—
·0546875		1/32	1/64	1/128	·3046875	1/4	1/32	1/64	1/128
·0625000	1/16	—	—	—	·3125000	5/16	—	—	—
·0703125	1/16	—	—	1/128	·3203125	5/16	—	—	1/128
·0781250	1/16	—	1/64	—	·3281250	5/16	—	1/64	—
·0859375	1/16	—	1/64	1/128	·3359375	5/16	—	1/64	1/128
·0937500	1/16	1/32	—	—	·3437500	5/16	1/32	—	—
·1015625	1/16	1/32	—	1/128	·3515625	5/16	1/32	—	1/128
·1093750	1/16	1/32	1/64	—	·3593750	5/16	1/32	1/64	—
·1171875	1/16	1/32	1/64	1/128	·3671875	5/16	1/32	1/64	1/128
·1250000	1/8	—	—	—	·3750000	3/8	—	—	—
·1328125	1/8	—	—	1/128	·3828125	3/8	—	—	1/128
·1406250	1/8	—	1/64	—	·3906250	3/8	—	1/64	—
·1484375	1/8	—	1/64	1/128	·3984375	3/8	—	1/64	1/128
·1562500	1/8	1/32	—	—	·4062500	3/8	1/32	—	—
·1640625	1/8	1/32	—	1/128	·4140625	3/8	1/32	—	1/128
·1718750	1/8	1/32	1/64	—	·4218750	3/8	1/32	1/64	—
·1796875	1/8	1/32	1/64	1/128	·4296875	3/8	1/32	1/64	1/128
·1875000	3/16	—	—	—	·4375000	7/16	—	—	—
·1953125	3/16	—	—	1/128	·4453125	7/16	—	—	1/128
·2031250	3/16	—	1/64	—	·4531250	7/16	—	1/64	—
·2109375	3/16	—	1/64	1/128	·4609375	7/16	—	1/64	1/128
·2187500	3/16	1/32	—	—	·4687500	7/16	1/32	—	—
·2265625	3/16	1/32	—	1/128	·4765625	7/16	1/32	—	1/128
·2343750	3/16	1/32	1/64	—	·4843750	7/16	1/32	1/64	—
·2421875	3/16	1/32	1/64	1/128	·4921875	7/16	1/32	1/64	1/128
·2500000	1/4	—	—	—	·5000000	1/2	—	—	—

TABLE OF THE FRACTIONAL PARTS OF AN INCH WITH CORRESPONDING DECIMALS—(*Continued.*)

Decimals.		Fractions.				Decimals.		Fractions.			
·5078125	=	$\frac{1}{2}$	—	—	$\frac{1}{128}$	·7578125	=	$\frac{3}{4}$	—	—	$\frac{1}{128}$
·5156250		$\frac{1}{2}$	—	$\frac{1}{64}$	—	·7656250		$\frac{3}{4}$	—	$\frac{1}{64}$	—
·5234375		$\frac{1}{2}$	—	$\frac{1}{64}$	$\frac{1}{128}$	·7734375		$\frac{3}{4}$	—	$\frac{1}{64}$	$\frac{1}{128}$
·5312500		$\frac{1}{2}$	$\frac{1}{32}$	—	—	·7812500		$\frac{3}{4}$	$\frac{1}{32}$	—	—
·5390625		$\frac{1}{2}$	$\frac{1}{32}$	—	$\frac{1}{128}$	·7890625		$\frac{3}{4}$	$\frac{1}{32}$	—	$\frac{1}{128}$
·5468750		$\frac{1}{2}$	$\frac{1}{32}$	$\frac{1}{64}$	—	·7968750		$\frac{3}{4}$	$\frac{1}{32}$	$\frac{1}{64}$	—
·5546875		$\frac{1}{2}$	$\frac{1}{32}$	$\frac{1}{64}$	$\frac{1}{128}$	·8046875		$\frac{3}{4}$	$\frac{1}{32}$	$\frac{1}{64}$	$\frac{1}{128}$
·5625000		$\frac{9}{16}$	—	—	—	·8125000		$\frac{13}{16}$	—	—	—
·5703125		$\frac{9}{16}$	—	—	$\frac{1}{128}$	·8203125		$\frac{13}{16}$	—	—	$\frac{1}{128}$
·5781250		$\frac{9}{16}$	—	$\frac{1}{64}$	—	·8281250		$\frac{13}{16}$	—	$\frac{1}{64}$	—
·5859375		$\frac{9}{16}$	—	$\frac{1}{64}$	$\frac{1}{128}$	·8359375		$\frac{13}{16}$	—	$\frac{1}{64}$	$\frac{1}{128}$
·5937500		$\frac{9}{16}$	$\frac{1}{32}$	—	—	·8437500		$\frac{13}{16}$	$\frac{1}{32}$	—	—
·6015625		$\frac{9}{16}$	$\frac{1}{32}$	—	$\frac{1}{128}$	·8515625		$\frac{13}{16}$	$\frac{1}{32}$	—	$\frac{1}{128}$
·6093750		$\frac{9}{16}$	$\frac{1}{32}$	$\frac{1}{64}$	—	·8593750		$\frac{13}{16}$	$\frac{1}{32}$	$\frac{1}{64}$	—
·6171875		$\frac{9}{16}$	$\frac{1}{32}$	$\frac{1}{64}$	$\frac{1}{128}$	·8671875		$\frac{13}{16}$	$\frac{1}{32}$	$\frac{1}{64}$	$\frac{1}{128}$
·6250000		$\frac{5}{8}$	—	—	—	·8750000		$\frac{7}{8}$	—	—	—
·6328125		$\frac{5}{8}$	—	—	$\frac{1}{128}$	·8828125		$\frac{7}{8}$	—	—	$\frac{1}{128}$
·6406250		$\frac{5}{8}$	—	$\frac{1}{64}$	—	·8906250		$\frac{7}{8}$	—	$\frac{1}{64}$	—
·6484375		$\frac{5}{8}$	—	$\frac{1}{64}$	$\frac{1}{128}$	·8984375		$\frac{7}{8}$	—	$\frac{1}{64}$	$\frac{1}{128}$
·6562500		$\frac{5}{8}$	$\frac{1}{32}$	—	—	·9062500		$\frac{7}{8}$	$\frac{1}{32}$	—	—
·6640625		$\frac{5}{8}$	$\frac{1}{32}$	—	$\frac{1}{128}$	·9140625		$\frac{7}{8}$	$\frac{1}{32}$	—	$\frac{1}{128}$
·6718750		$\frac{5}{8}$	$\frac{1}{32}$	$\frac{1}{64}$	—	·9218750		$\frac{7}{8}$	$\frac{1}{32}$	$\frac{1}{64}$	—
·6796875		$\frac{5}{8}$	$\frac{1}{32}$	$\frac{1}{64}$	$\frac{1}{128}$	·9296875		$\frac{7}{8}$	$\frac{1}{32}$	$\frac{1}{64}$	$\frac{1}{128}$
·6875000		$\frac{11}{16}$	—	—	—	·9375000		$\frac{15}{16}$	—	—	—
·6953125		$\frac{11}{16}$	—	—	$\frac{1}{128}$	·9453125		$\frac{15}{16}$	—	—	$\frac{1}{128}$
·7031250		$\frac{11}{16}$	—	$\frac{1}{64}$	—	·9531250		$\frac{15}{16}$	—	$\frac{1}{64}$	—
·7109375		$\frac{11}{16}$	—	$\frac{1}{64}$	$\frac{1}{128}$	·9609375		$\frac{15}{16}$	—	$\frac{1}{64}$	$\frac{1}{128}$
·7187500		$\frac{11}{16}$	$\frac{1}{32}$	—	—	·9687500		$\frac{15}{16}$	$\frac{1}{32}$	—	—
·7265625		$\frac{11}{16}$	$\frac{1}{32}$	—	$\frac{1}{128}$	·9765625		$\frac{15}{16}$	$\frac{1}{32}$	—	$\frac{1}{128}$
·7343750		$\frac{11}{16}$	$\frac{1}{32}$	$\frac{1}{64}$	—	·9843750		$\frac{15}{16}$	$\frac{1}{32}$	$\frac{1}{64}$	—
·7421875		$\frac{11}{16}$	$\frac{1}{32}$	$\frac{1}{64}$	$\frac{1}{128}$	·9921875		$\frac{15}{16}$	$\frac{1}{32}$	$\frac{1}{64}$	$\frac{1}{128}$
·7500000		$\frac{3}{4}$	—	—	—	·1000000		1	—	—	—

741. Explain the following formula:—$x = \frac{a}{b}$.

The letter a cannot, of course, be divided by the letter b—they are signs representing quantities, and x represents an unknown quantity, or the quantity obtained is the number represented by x. We will suppose a to represent a quantity of air passing through a mine, say 60,000 cubic feet a minute, and b to represent the area of the airway, say 60 square feet, and x to represent the velocity; its value would be found by putting 60,000 in the place of a in the formula, and 60 in the place of b; then the value of x would be $\frac{60{,}000}{60} = 1{,}000$.

742. How would you find the circumference of a circle?

To find the circumference of a circle, multiply the diameter by 3·1416. To find the diameter, divide the circumference by 3·1416.

743. How would you find the area of a circle?

To find the area of a circle, square the diameter, and multiply the result by ·7854.

744. Having a circular airway 3 ft. in diameter, how would you find the area and diameter of another airway to equal three times the area of the 3 ft. airway?

Rule.—Multiply ·7854 by the square of the diameter of the 3 ft. airway, then multiply that product by the number of times the airway requires to be enlarged, and the square root of that product multiplied by 1·12837 will give the diameter of the larger airway?

Example.—$\cdot 7854 \times 3^2 = 7\cdot 0686 \times 3 = 21\cdot 2058$, area of the airway required.

And $\sqrt{21\cdot 2058} = 4\cdot 60 \times 1\cdot 12837 = 5\cdot 19$, diameter of airway required.

745. A hoppit or sinking "bowk" has inner dimensions, as follows:—Depth 3 ft. 6 in., diameter 3 ft. 3 in. at top and 2 ft. 6 in. at bottom; how many cubic feet and gallons of water will it hold? Also give the weight of water.

Rule.—$3{\cdot}25 + 2{\cdot}5 = 5{\cdot}75 \div 2 = 2{\cdot}875^2 \times {\cdot}7854 = 6{\cdot}52$ (mean area of bowk) and $6{\cdot}52 \times 3{\cdot}5 = 22{\cdot}82$ cubic contents in feet, and $22{\cdot}82 \times 6{\cdot}24$ (gallons in a cubic foot of water) $= 142{\cdot}4$ gallons, and $142{\cdot}4 \times 10$ (the weight of a gallon of water in pounds) $= 1{,}424$ lb. or 12·70 cwt.

746. Can you give a summary of the contractions of metrical units as used in French measurements?

Yes; the following contractions have been adopted by the International Metrical Congress at Paris, and are recommended for general use:—(1.) Length: Kilometre *km*; metre, *m*; decimetre, *dm*; centimetre, *cm*; millimetre, *mm*. (2.) Surface: Square kilometre, km^2; square metre, m^2; square decimetre, dm^2; square centimetre, cm^2; square millimetre, mm^2; hectare, *ha*; are, *a*. (3.) Cubic measure: Cubic kilometre, km^3; cubic metre, m^3; cubic decimetre, dm^3; cubic centimetre, cm^3; cubic millimetre, mm^3. (4.) Hollow measure: Hectolitre, *hl*; litre, *l*; decilitre, *dl*; centilitre, *cl*. (5.) Weight: Ton (1,000 kilogrammes), *t*; metric hundredweight (100 kilogrammes), *g*; kilogramme, *kg*; decagramme, *dka*; gramme, *g*; decigramme, *dg*; centigramme, *cg*; milligramme, *mg*. Italic letters are used for these contractions, and no stop is to be used at the right of them. The contractions succeed the figures to which they refer on the same line, and are placed after the last decimal when figures are used that contain decimal fractions.

747. Seventy scores of tubs of coal are raised each day, and the average weight of coal in each tub is 8½ cwt., the score consisting of 21 tubs. What is the daily output?

Answer: $$\frac{70 \times 21 \times 8{\cdot}5}{20} = 624 \text{ tons } 15 \text{ cwt., or}$$ 624·75 tons.

748. If 100 scores of tubs are raised in a day, the weight of coal in each tub averaging 10 cwt. and the score consisting of 20 tubs—supposing also that the colliery works 5½ days in the week—what is the output per week?

Answer: $$\frac{100 \times 20 \times 5{\cdot}5 \times 10}{20} = 5{,}500 \text{ tons per week.}$$

749. How many tons of coal are there in a pillar of coal 100 yards long and 30 yards broad, the seam being 4 ft. 6 in. thick, and the coal weighing 80 lb. per foot?

Rule:—Put all the dimensions into feet, multiply them all together and by 80, and divide by the number of pounds in a ton. Thus: $\frac{300 \times 90 \times 4{\cdot}5 \times 80}{2{,}240} = 4{,}339$ tons 5 cwt. 2 qr. 24 lb.

750. What weight of material will have to be raised in sinking an elliptical shaft 15 ft. × $5\frac{1}{2}$ ft., 40 fathoms deep, supposing it averages 130 lb. per cubic foot?

The superficial area of the pit would be $15 \times 5\frac{1}{2} \times {\cdot}7854 = 64{\cdot}7955$ ft., and the cubic contents would be, in feet, $40 \times 6 \times 64{\cdot}7955 = 15{,}550$ cubic feet, and the weight would be $\frac{15{,}550 \times 130}{2{,}240} = 902\frac{102}{224}$ tons.

751. A colliery raises 6,000 tons of coal in one week, and £1,000 are paid in wages; what is the cost per ton?

The rule is as follows:—First reduce the pounds to shillings, then divide the product by the number of tons, which will give the cost per ton in shillings; then multiply the remainder by 12 to bring it to pence. Divide this product also by the number of tons, and you will have the cost per ton in shillings and pence; add cyphers to the remainder and divide by the number of tons, and you will have the price per ton in shillings, pence, and fractional parts of a penny.

Example.—£1,000 × 20 = 20,000 shillings. Rule applied

```
Tons.          s.
6,000)20,000(3
      18,000
      ------
       2,000
          12
      ------   d.
6,000)24,000(4
      24,000
```

The cost per ton in this case would be 3s. 4d., and no fraction over.

752. A colliery raises 6,000 tons of coal per week, and it takes £1,000 to pay wages, which is an average of 3s. 4d. per ton; what will be the reduction in the cost per ton if the output be increased to 7,500 tons, supposing no staff of men to be paid but the coal-getters, and their price is 1s. per ton, which will represent £1,075 to be paid in wages?

Rule.—£1,075 × 20 = 21,500 shillings.

$$\begin{array}{rrl}
\text{Tons.} & & \text{s.}\\
7{,}500) & 21{,}500 & (2\\
 & 15{,}000 & \\ \cline{2-2}
 & 6{,}500 & \\
 & 12 & \\ \cline{2-2}
 & & \text{d.}\\
7{,}500) & 78{,}000 & (10\\
 & 75{,}000 & \\ \cline{2-2}
7{,}500) & 30{,}000 & (\tfrac{4}{10}\\
 & 30{,}000 &
\end{array}$$

The answer would be 2s. 10d. and four-tenths of a penny per ton, or a reduction in the cost per ton of 5d. and six-tenths.

753. If the output of a colliery is 6,000 tons per week, 2,000 tons of which is slack, what is the percentage of coal and slack?

This is a sum in simple proportion, and should be treated thus, viz.: If 6,000 tons yield 2,000 tons of slack, what will 100 yield? Example:—6,000 : 2,000 :: 100 : 33·33 per cent. slack; 6,000 : 4,000 :: 100 : $\frac{66\cdot66}{99\cdot99}$ per cent. coal.

754. Required the quantity of water in cubic feet discharged per second through an opening in the side of a dam, the width of the opening being 6½ ft. and depth ·75 ft.

Rule.—When the aperture is under a given head, multiply the area of the aperture in feet by the square root of the depth also in feet, and by 5·1; the product is the quantity discharged in cubic feet per minute.

Square root of ·75 = ·866.

Then $\frac{6{\cdot}5 \times {\cdot}75 \times {\cdot}866 \times 5{\cdot}1 \times 2}{3} = 14{\cdot}3839$ cubic feet.

755. What weight on the end of a lever 12 ft. in length will equipoise 2 tons on the other end, the distance of the fulcrum being 6 in. from the weight to be equipoised, the weight of the lever not taken into account?

Rule.—$\frac{4{,}480 \times 6 = 26{,}880}{138} = 194{\cdot}7$ lb., weight required.

756. What quantity of coals will be contained in a heap that measures 16 ft. long, 6½ ft. wide, and 18 ft. in height, allowing 45 cubic feet capacity per ton?

Rule.—$\frac{16 \times 6{\cdot}5 \times 18}{45} = 41{\cdot}6$ tons in the heap.

757. An iron plate 7 ft. long, 6 ft. broad, and ⅝ in. in thickness, how many cubic feet does it contain, and what is its weight at 25 lb. per square foot?

Rule.—7 × 6 × ·052 = 2·184 cubic feet; then 7 × 6 × 25 = $\frac{1{,}050}{112}$ = 9 cwt. 1 qr. 14 lb.

758. How would you extract the square and cube root? Give examples.

To extract the square root, if a whole number, point the unit figure and each alternate figure upwards; if a fraction place a cypher before the decimal to take the unit point, then point each alternate figure in the decimal. Find the square of the greatest number which does not exceed the figure or figures included in the last point and subtract. Bring down two more figures. Double the root already found and find a new figure of the root. Add this on to the divisor, which multiply by the new figure in the root. Subtract the product from the figures brought down, and so on to completion of sum. Example: (1) What is the square root of 390,625?

$$\begin{array}{r|l}
6\,) & 3\dot{9}0,\dot{6}2\dot{5}\,(625\text{, answer.} \\
 & \underline{36} \\
122\,) & \;\;306 \\
 & \;\;\underline{244} \\
1,245\,) & \;\;\;6,225 \\
 & \;\;\;\underline{6,225}
\end{array}$$

(2) Extract the square root of ·00390625.

$$\begin{array}{r|l}
0\,) & \dot{0}\cdot0\dot{0}3\dot{9}0\dot{6}2\dot{5}\,(\cdot0625\text{, answer.} \\
 & \;\underline{\cdot00} \\
6\,) & \;\;\;39 \\
 & \;\;\;\underline{36} \\
122\,) & \;\;\;306 \\
 & \;\;\;\underline{244} \\
1,245\,) & \;\;\;\;6225 \\
 & \;\;\;\;\underline{6225}
\end{array}$$

(3) Extract the square root of $\frac{5}{8}$. Reduce the fraction to a decimal. $\frac{5}{8} = \cdot625$, and proceed as above.

To extract the cube root of a given number, point from unity, missing two. Find the greatest cube contained in the figure included in last point. Subtract and bring down next period. For new divisor square the part already found and multiply by 300. Add the product of the root already found × 30 × new figure of root; also add the square of the new figure found. Multiply the sum by last figure found in root and subtract product from figure brought down, and so on. Example: (1) What is the cube root of 1,092,727?

```
                                 1³ =)1̇,092̇,727̇(103
                                     )1
                                       ——
              1² × 300 = 300)   092,727
                            )
          10² × 300 = 30,000
        10 × 30 × 3 =    900
                 3² =      9 )  92,727
                  ——30,909)
```

(2) What is the cube root of 2,305·199161?

```
                                  1³ )2̇,305̇·199̇161̇(13·21
                                     )1
               1² × 300 = 300         —
            1 × 30 × 3 =  90     )1,305
                    3² =   9
                       ——399)1,197
           13² × 300 = 50,700     ————
         13 × 30 × 2 =    780    ) 108·199
                  2² =      4
                 ——51,484)  102,968
       132² × 300 = 5,227,200     ——————
     132 × 90 × 1 =      3,960  )    5,231,161
               1² =          1
             ———5,231,161)    5,231,161
```

CHAPTER XIII.

LAND AND MINE SURVEYING.

759. What is land surveying; and what are the instruments chiefly required?

Surveying in a general sense denotes the art of measuring the angular and linear distances of objects, so as to be able to delineate their several positions on paper, and to ascertain the superficial area or space between them. It is a branch of applied mathematics, and pre-supposes a good knowledge of arithmetic and geometry. The instruments required are the chain, the arrows, the theodolite or compass, and the cross-staff.

760. Can you give a description of the chain?

It is an iron measure 66 ft., or 22 yards, or four poles in length, divided into 100 links:—

$$\left(\frac{66 \text{ ft.} \times 12 \text{ in.}}{100}\right), 7{\cdot}92 \text{ in. each.}$$

At every 10 links there is fastened a piece of brass, cut into ears to denote the number of tens, and at the end of each pole there is generally a swivel to prevent its getting into a snarl.

761. What is an off-set staff, and of what use is it?

It is a rod 10 links long, each link being painted a different colour, and about 1½ in. diameter, used for measuring offsets in the field.

762. What is meant by arrows, and what is their use in surveying.

They are small iron rods of about 16 or 18 in., which, in measuring, are used by the leader of the chain, one of which he puts perpendicularly into the ground at the end of every chain's length; these are collected by the measurer, who generally conducts the chain behind. Ten of them are generally used, and when they have all been put in, a change is made, and they are carried forward and handed to the leader.

763. Describe the theodolite and its use.

This is an instrument for measuring angles, taking sights, &c. The theodolite illustrated (fig. 339) is manufactured by Messrs. Davis and Son, of London and Derby, and is fitted with the Hoffman patent joint and centering movement. This combination facilitates greatly the labour of setting up, levelling and fixing the theodolite over a given point. There are two methods of measuring angles with the theodolite; first, the angle measured from the meridian line to the chain line; second, the angle measured between two fixed objects. In the first the theodolite is truly adjusted and placed firmly on the ground, and the parallel plates as nearly level as possible. The centre of the instrument must be exactly over the station-peg. The index is then fixed on the vertical arc, K, at zero, and the instrument is levelled by the four screws, T, by turning them slowly contrary ways, raising one side and depressing the other until the bubble is in the centre of the level, P. The instrument should then be turned half round and the operation repeated with the other two screws. The zero of the horizontal limb, A, must now be brought to the lower limb at 360 degs., opposite it being 180 degs., and then fixed by the clamp screw on the upper plate. The head of the instrument must then be moved until the north end of the needle points exactly to 360 degs. It should then be fixed by means of the lower clamp screw, and the clamp screw on the upper plate loosed, and the telescope turned round until the cross wires cut the object set up on the chain lines. The angle can then be read on the limb, A, by the microscope, R, as for instance, 12 degs. 40 min. N.E.

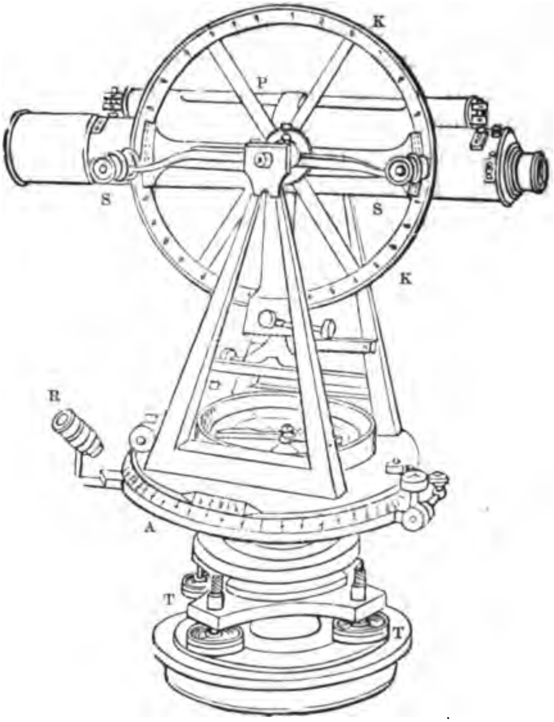


Fig. 339.

The same angle may be read by the needle, if correct. This operation should always be repeated, and if there is a slight difference between the two readings, the mean should be taken.

764. Give a description of the compass or dial.

For an illustration of the dial, see fig. 340, which is a Hedley dial, manufactured by Messrs. John Davis and Son, of London and Derby; the compass-box is divided into 360 degs. on the outer circle; the inner circle is subdivided into minutes. On the upper part are a magnetic needle and two sights, B B, perpendicular to the meridian line in the box; in each sight there is a large and small aperture or slit, one over the other; these are alternate, a horse-hair runs through the middle of each aperture, and the circle holes cross at right angles by another horse-hair. The two sights are made to fold down for the convenience of packing. Underneath the compass-box is a pin or screw, E, to fasten the two plates together at 360 degs., and a spring to throw the needle off the point, to preserve it when not in use. This instrument is made to turn in a vertical direction for taking angles of altitude and depression; for this purpose the arc, C, is attached to the instrument. Two spirit levels, DD, are attached to the upper part for levelling and adjusting the instrument. The instrument stands on tripod legs, and works on a ball and socket, by which it can be adjusted to take vertical and horizontal angles.

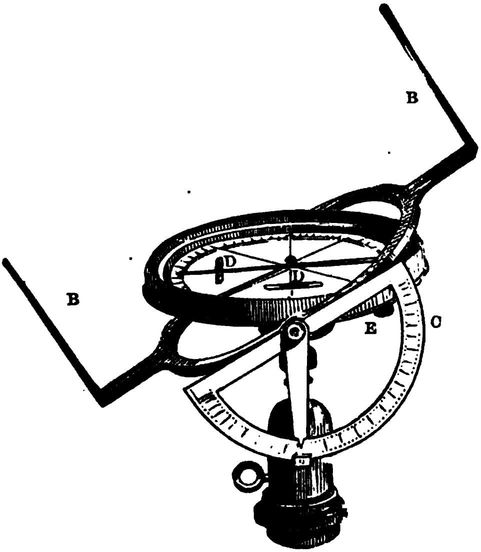


Fig. 340.

765. Give a description of the best and simplest dial for mining purposes that has come under your notice.

It is well, if possible, to avoid surveying underground workings with the fast needle—a method which involves the expenditure of much time and labour—and it can be done by using the dial shown at fig. 341, a most compact dial, combining the advantages of the best Hedley with the outside vernier of the theodolite. An improvement in this dial is an arrangement by which the bearings are taken simultaneously with loose needle and vernier, the latter automatically checking the former, so that any error arising from incorrect reading or from any local attraction

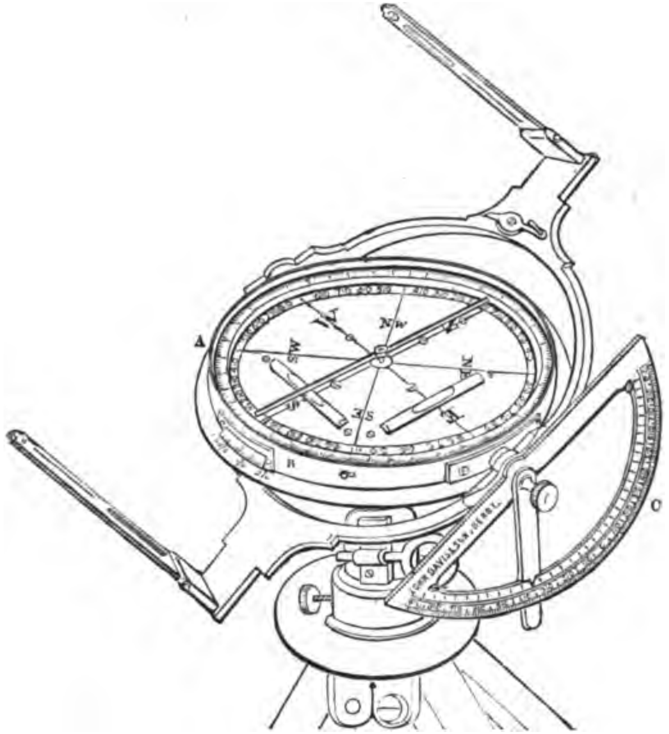


Fig. 341.

is detected. For accurate surveying this instrument can therefore be relied upon, which is more than can be said of every miner's dial. A is the divided plate, which is clamped to the legs; B is the vernier, which reads on the divided plate, A, and is fixed to the body; C is an arc, which can be attached to the dial when surveying any dip or rise workings. Fig. 342 illustrates a further improvement on the Hedley dial. It consists of the improved Hedley dial as described, with the addition of an excellent telescope, which is interchangeable with the ordinary sights; an improved arc, which is very compact and a fixture; and the Hoffman patent joint. The dial illustrated in fig. 343 is a miner's dial, which combines the Lean's circumferentor with the Hoffman patent joint. The special feature of this instrument is that it possesses a telescope mounted on a semicircle, and enables the operator to take the dip of stratum up to 90 degs. The instruments described are manufactured by Messrs. Davis and Son, of London and Derby.

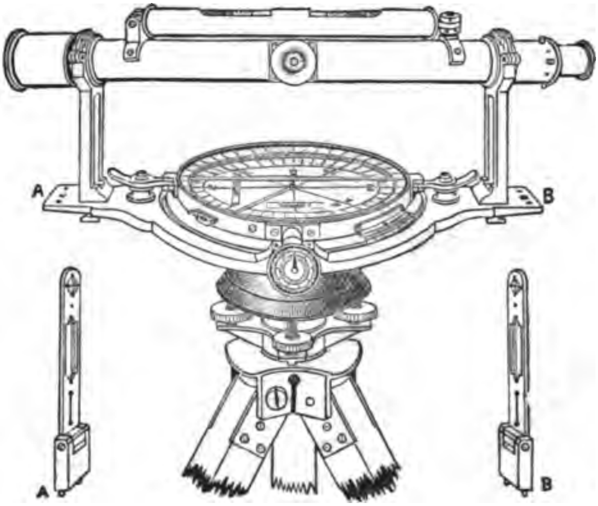


Fig. 342.

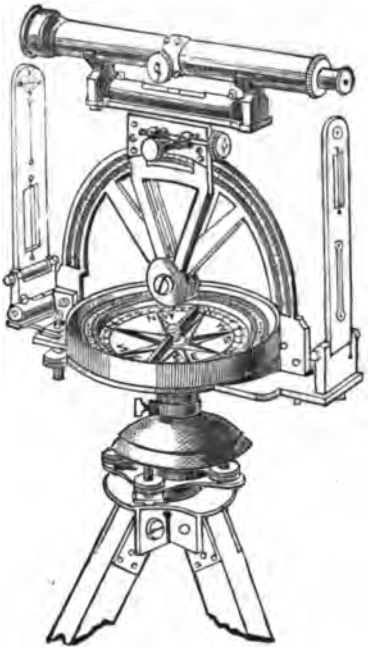


Fig. 343.

766. Give a description of an underground survey made with the improved Hedley dial, with outside vernier.

The magnetic needle without a check is not a safe guide in underground surveying. Ferruginous substances are plentiful in almost all mines—some visible enough, some, however, not visible to the senses of the surveyor. Such substances act upon the needle of the dial, and if no method be adopted to measure the amount of the attraction, or to dispose of its erroneous readings, these surveys must be doubtful and worthless. The costly and cumbersome theodolite is out of all question for general use in mines, and its angular readings give no idea as to the separate bearings of the headways, and no check is obtained to the readings. Davis' new and improved Hedley dial not only meets all the requirements of the mining surveyor, but by its aid surveys can be made with mathematical certainty. The improved dial counts from the north from left to right, 10, 20, 30, 40, &c., and the outside check figures commence at the vernier, and the figures, to facilitate their reading by the operator, also count from left to right, 10, 20, 30, 40, &c. In commencing an underground survey, do not really commence at the pit's eye, because it is next to impossible to get a true reading, on account of the ironwork there. Select some disused road (such are to be found in most pits) and take from two separate stations its magnetic bearing, then tighten the collar attached to the ball and socket, slacken the clamping screw, turn the sights of the dial by means of the rack and pinion screw, until the vernier reads the same degree as the bearing just taken; the bearing and length thus taken will serve as the bases of subsequent operations. Then tighten the clamping screw and slacken the collar, and by means of the loose collar direct the sights of the instrument between the same stations as before, and if the needle and vernier readings are the same, the dial is in adjustment to survey the whole of the underground workings from the base line just taken. We will suppose, in order to be understood, the bearing of the needle and the vernier reading to be 40 degs. 200 links. Set up the instrument on the end of the line from which you wish to continue the survey, and by means of the loose collar direct the sights to the other end of the line, and if the angle reads as we have supposed, 40 degs., tighten the collar, slacken the clamping screw, and by means of the rack and pinion screw, direct the sights to the next station, which suppose to read 30 degs. 100 links. Again tighten the clamping screw and slacken the collar, and move the instrument to the next station. Set up the instrument truly over the station, and by means of the loose collar direct the sights to the last station. (If the needle and vernier readings agree there is no attraction. If they differ, the amount of magnetic attraction is the difference between the magnetic and vernier readings. The vernier reading must always be taken in preference to the magnetic, because it will be found in practice that, when there is no attraction, the magnetic and vernier readings will again agree—and this will be found the case throughout the survey, and give undoubted proof that the work is right.) Again tighten the collar and slacken the clamping screw, and by the screw of the rack and pinion direct the sights to the next station, which suppose to be 20 degs. and 100 links. Then tighten the clamping screw and slacken the collar, and move the instrument to the next station. Fix the instrument truly over the station, and by means of the loose collar direct the sights to the last station. Then tighten the collar, slacken the clamping screw, and by means of the screw of the rack and pinion direct the sights to (we will suppose the pit shaft) the next station, which is 10 degs. 100 links. It is here necessary to observe two things:—First, that in all the sights taken in the direction of the pit shaft, the eye of the surveyor must be at the north sight; and in taking a sight *from* the pit shaft, must be at the south sight. Secondly, if, as we have supposed, the base line is some distance from the pit's eye, the survey notes must be entered from the top of the notebook downwards, instead of upwards as is usual—then the bearings and the notes will be precisely the same as they would have been had the survey commenced at the pit shaft. The plotting also may be done as in ordinary cases. In every survey, by using the improved Hedley dial, the work is verified as it goes on, the true magnetic bearings registered, which cannot be said of any other instrument, the theodolite not excepted. If no disused road can be found in the pit, then get up the tram rails—say, for 20 yards—and remove all other iron for the same distance, so that one magnetic bearing may be obtained without attraction. The survey may then go on as before described. It may, perhaps, be advisable here to note that some line used in making the surface survey (say the base line, or some principal line) should be marked out upon the surface by fixing in the ground at least two or three permanent marks as stations, and corresponding marks and stations legibly marked upon the colliery plan. The mining surveyor may then at any time check the pit shafts and boundaries, and prove the accuracy of the plan. If the surveyor will take the bearing of this line, he can draw the magnetic meridian for any instrument. It is a fact that different instruments, especially if they are made by different makers, vary in reading the same line. The writer has known them vary 1¾ degs.; but if the foregoing directions are attended to, and the bearing of some line taken, and the magnetic meridian fixed accordingly, uniformity instead of diversity would be the result. This method also will meet the difficulty of the variation of the compass, because the true magnetic meridian may be fixed at any time, and as often as it is considered necessary by the surveyor.

767. What are the advantages claimed for Hoffman's patent improved joint over the ball and socket joint?

The ordinary ball and socket joint has many defects. With it it is almost impossible to level up exactly; or after fixing, a second glance will show the bubble out of place, thus making it necessary to level again. As in underground workings the instrument has often to be set up under difficulties, especially when the strata are greatly inclined, much of the time of the surveyor is spent in adjusting the instrument, the assistants are kept waiting, the survey goes on slowly, and even then is apt to be inaccurate. The Hoffman improved joint (fig. 344), manufactured by Messrs. John Davis and Sons, has many advantages over the ball and socket joint, among which the following may be mentioned:—(1.) The plumb line is suspended from D, the actual centre of the dial, which cannot be achieved with the ball and socket. (2.) The rubbing surface is some ten times greater, and therefore the joint is far more rigid. (3.) The joint is manipulated with greater ease and despatch; a slight turn of the milled flange, AA, from right to left liberates the two concentric balls, B and D, the dial is then levelled up, and a slight turn of the flange from left to right secures the joint. (4.) Only one hand is required to manipulate the joint. (5.) The total height of the improved joint is 3 in., the ordinary ball and socket $3\frac{5}{8}$ in. (6.) The length of the centre is $2\frac{1}{8}$ in., that of the ball and socket is barely $1\frac{1}{2}$ in., thus the dial reverses with greater accuracy. While possessing many and important advantages, the joint is no heavier than the ball and socket.

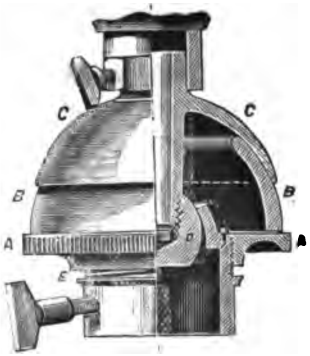


Fig. 344.

768. Explain the dumpy level and its use.

Fig. 345 is the improved dumpy level. This instrument is used for levelling in a number of cases. It is used when a line of country has to be levelled, to show the true surface of the ground, called a section; to take the height of hills and mountains; to level for water-courses and for other water levels; and to level between two points to find the outcrop of coal, &c.; it is frequently used for levelling large buildings, such as engine-houses, &c., and in some instances is used for levelling and taking heights in the underground workings. A is the telescope; B B are the achromatic eye-glass and object glass, and diaphragm with three cobwebs; E E is the spirit level for adjusting the instrument; F F the parallel plate screws, by which the instrument is brought to a level; H H are tripod legs on which the instrument stands.

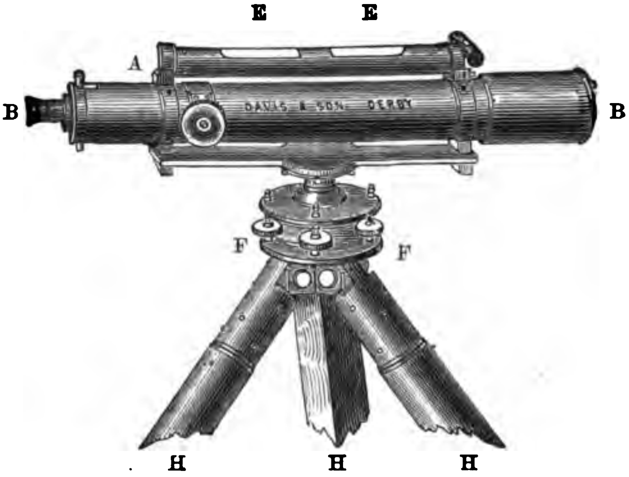


Fig. 345.

769. In levelling with instruments, from what causes do errors occur?

Errors occur from the curvature of the earth's surface. To allow for this the following formula is used:— $\frac{D^2}{800}$ = inches to be deducted from the reading, D being the number of chains traversed. Errors also occur from refraction, but only amounting to one-seventh of the above. Neither of these facts need be taken into account in ordinary cases.

770. Of what use is the barometer in levelling?

The height and level of hills and mountains can be roughly estimated with the barometer, as the mercury falls $\frac{1}{10}$ in. for every 90 ft. ascent.

771. How would you use the dumpy level?

Suppose it is required to determine the difference of level between the points M and N. Set up the instrument at A (fig. 346), and take a reading on the staff at B (which

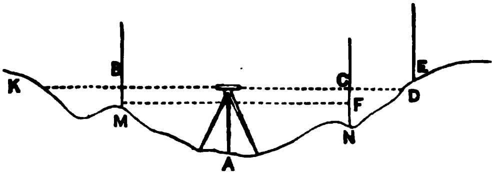


Fig. 346.

set down at 2·10 ft.) Now, if the distance between M and N can be seen by the telescope, turn the level round on its axis, and take a reading on the staff at C (which say equals 5·35). Bearing in mind that both B C and M F are horizontal lines, it is evident that the difference of level between the two points M and N is equal to the height F N. But if F N = C N − C F, and C F = B M, consequently F N = C N − B M. But by the readings C N = 5·35, B M = 2·10, therefore F N, or the difference of level between the two points M and N = 5·35 − 2·10 = 3·25 ft.

Or we may suppose the reading taken at A (fig. 347), to

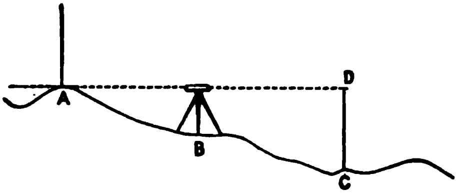


Fig. 347.

be exactly at the zero of the staff, and the reading at D to be exactly at the top line of the graduations of the staff, then the difference of level between A and C equals the precise length of the staff. Were the point C situated lower, it is evident that the top of the staff would drop below the dotted line and that no reading could be observed. It is barely possible that, in practice, two readings would be obtained, of which one would equal zero, and the other the exact length of the staff, but the illustration is given to show the maximum difference of level that it is first possible to ascertain without shifting the instrument. Besides this, it shows that the setting up of the level is not a matter of hazard or mere chance, but should be regulated according to the position of the points at which the level is required.

772. Give a description of Jee's pit levelling staff for underground levelling.

Mr. Jee, in giving an explanation of his pit levelling staff, says:—"The levelling staff which I have designed consists of three lengths sliding into each other, and nearly resembles the ordinary Sopwith staff in that respect. The bottom length is graduated upwards in the ordinary way, and is 3 ft. in length; but of course any other length could be adopted that might be thought more convenient. At the top of the first division of the levelling staff a band is attached, about 2 in. wide, which is graduated upwards, and forms an accurate continuation of the scale on the lower division of the staff. The last-mentioned band passes over a brass roller attached to the top or innermost division of the staff, and is from thence carried down and under a brass drum (on which it is wound) fixed just below the roller to the top of the same staff, the band being kept in tension by means of a box spring on one side attached to the axis of the cylinder. It will be seen from the above arrangement that when the second division of the staff is drawn out, the band unwinds, and gives a continuous reading up to 5 ft. 8 in., or for any intermediate distance that the height of the roof will allow, the band being kept in tension at the required elevation, and lying flat against the face of the second division of the staff. In the same way, when the third division is drawn out, a continuous reading may be obtained up to 9 ft., or for any intermediate distance, as before. The second and third divisions of the staff are kept fixed in any required position by means of clamping screws, which are fixed to the sides, and the usual spring catches are also inserted in the back, which come into action when the divisions are drawn out to their full length. The whole weight of the staff only just exceeds 5 lb., so that it is sufficiently light and portable, which is an important consideration in underground work. Figs. 348 and 349 are side and front views of the staff, drawn to a scale of 3 in. to a foot. Messrs. John Davis and Son are the makers.

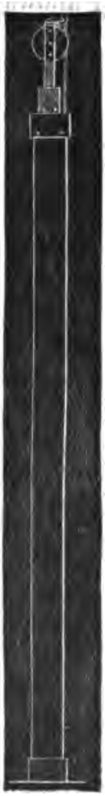


Fig. 348.

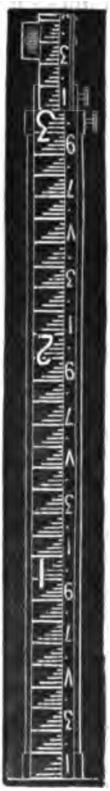


Fig. 349.

773. How is uneven ground or hills measured with the chain?

Uneven ground should be measured horizontally, the surface of a hill thus measured giving the same contents when calculated as the level base upon which it is supposed to stand. In measuring on sloping ground it is necessary, therefore, to make certain corrections or allowances, which may be done in two ways. (1.) By "plumbing" up or down hill. In chaining up-hill, the forward chainman will hold his end of the chain on the ground, while the "follower" will, with the aid of a plumb-bob and string, hold his end of the chain as high as the forward end, and plumb over the point from which the measurement is to be taken. Assuring himself that the chain is level, he holds it firmly against the plumb string and calls to the forward chainman to "pull up." When the chain is as tight as desired, and the forward man in line, the "follower" says "all right," and the leader marks with an arrow the end of the chain. The chain is then carried forward to this mark, and other measurements made in like manner. Much practice is required to judge with accuracy by the eye alone what "level" is; therefore a third man is needed—usually the leader of the party—who stands a short distance aside from the chain, and by comparing the line between the two ends, and the plumb line, can with comparative accuracy secure a horizontal line. In chaining downhill the method of procedure is reversed. A 100 ft. chain suspended by the two ends will be somewhat shorter than when stretched out on the ground. It is therefore necessary, before commencing chaining, to compare the suspended chain with the "standard," allowance being made on the chain or by calculation in the office. On steep hills a 100 ft. chain would be too long, and often a 50 ft. chain would be unmanageable, and in such case perhaps the best instrument is a 20 ft. pole, made of light dry white pine, accurately spaced into feet and tenths, and shod at each end with brass. A small spirit level set into the top will be an advantage. If the grade of the hill is regular, and, by the level or gradometer the rise or fall per 100 ft. or the angle of the hill is known, rapid and accurate work can be done by chaining on the ground. The horizontal distance may be afterwards calculated. It will be the base of a triangle, of which the measured line is the hypothenuse, and the rise in that distance the perpendicular. Or, by multiplying the cosine of the observed angle by the distance measured, the result will be the horizontal distance corresponding to the measurement on the ground. Always bear in mind that the corrections are subtractive, the measurement on the hill being in excess of the distance required.

774. Can you give a table to reduce incline measure to level distance ?

Yes; the table of incline measure given on the following pages has been constructed by Mr. W. Fairley, M.E.

775. What precautions would you take in surveying a mine with a loose needle where safety lamps only are used ?

In surveying a mine with a loose needle where safety lamps are used, the surveyor must provide himself with a lamp that is entirely of copper or brass, else the bearings will be useless.

776. What precautions should be taken when surveying with a loose needle in underground workings ?

When taking horizontal or level bearings, all rails and other material that would attract the magnetic needle must be removed from 4 to 5 yards on either side of the dial, but when a sight is being taken up or down an incline, such material should be removed on the rise side of the dial 6 or 8 yards, and care should be taken to remove all iron signal wire to a similar distance. When a steel chain is used for measuring, this also must be removed to a sufficient distance.

777. Give two examples, with sketches, of the way in which an underground survey should be performed with a loose needle.

No. of Degs.	Inclination per Yard, in Inches.	One in	Horizontal Measure, Hypothenuse being 1.	Vertical Measure, Hypothenuse being 1.	Deduct Links per Chain.	Gravity due to Incline per Ton, in Pounds.	Square Yards per Acre
1	0·63	57·29	·99985	·01745	0·01	39·08	4840·72
2	1·26	28·68	·99939	·03490	0·06	78·18	4842·95
3	1·88	19·09	·99863	·05234	0·14	117·24	4846·63
4	2·51	14·29	·99756	·06976	0·24	156·26	4851·83
5	3·15	11·42	·99619	·08716	0·38	195·24	4858·51
6	3·78	9·51	·99452	·10453	0·55	234·14	4866·66
7	4·42	8·14	·99255	·12187	0·74	272·98	4876·32
8	5·06	7·11	·99027	·13917	0·97	311·74	4887·55
9	5·70	6·31	·98769	·15643	1·23	350·40	4900·92
10	6·34	5·67	·98481	·17365	1·52	388·97	4914·65
11	6·99	5·14	·98163	·19081	1·84	427·41	4930·57
12	7·65	4·70	·97815	·20791	2·19	465·71	4948·11
13	8·31	4·33	·97437	·22495	2·56	503·88	4967·31
14	8·97	4·01	·97030	·24192	2·97	541·90	4988·14
15	9·64	3·73	·96593	·25882	3·40	579·75	5010·71
16	10·32	3·48	·96126	·27564	3·87	617·43	5035·05
17	11·00	3·27	·95630	·29237	4·37	654·90	5061·17
18	11·69	3·07	·95106	·30902	4·89	692·20	5089·05
19	12·39	2·90	·94552	·32557	5·45	729·27	5118·87
20	13·10	2·74	·93969	·34202	6·03	766·12	5150·63
21	13·82	2·60	·93358	·35837	6·64	802·74	5184·34
22	14·54	2·47	·92718	·37461	7·28	839·12	5220·12
23	15·27	2·35	·92050	·39073	7·95	875·23	5258·01
24	16·02	2·24	·91355	·40674	8·65	911·09	5298·01
25	16·78	2·14	·90631	·42262	9·37	946·66	5340·33
26	17·56	2·05	·89879	·43837	10·12	981·94	5385·01
27	18·34	1·96	·89101	·45399	10·90	1016·93	5432·03
28	19·14	1·88	·88295	·46947	11·71	1051·61	5481·62
29	19·95	1·80	·87462	·48481	12·54	1085·97	5533·83
30	20·78	1·73	·86602	·5	13·40	1120·00	5588·78
31	21·62	1·66	·85717	·51504	14·28	1153·68	5646·48
32	22·49	1·60	·84805	·52992	15·19	1187·02	5707·21
33	23·37	1·54	·83867	·54464	16·13	1219·99	5771·04
34	24·28	1·48	·82904	·55919	17·10	1252·58	5838·07
35	25·20	1·42	·81915	·57358	18·08	1284·81	5908·56
36	26·15	1·37	·80902	·58778	19·10	1316·62	5982·54
37	27·12	1·32	·79864	·60181	20·14	1348·05	6060·30
38	28·12	1·28	·78801	·61566	21·20	1379·07	6142·05
39	29·14	1·23	·77715	·62932	22·28	1409·67	6228·01
40	30·21	1·19	·76604	·64279	23·40	1439·84	6318·20
41	31·29	1·15	·75471	·65606	24·53	1469·57	6413·05
42	32·41	1·11	·74314	·66913	25·69	1498·85	6512·90
43	33·56	1·07	·73135	·68200	26·86	1527·68	6617·89
44	34·76	1·03	·71934	·69466	28·07	1556·03	6728·38
45	36·00	1·00	·70711	·70711	29·29	1583·92	6844·76

No. of Degs.	Inclination per Yard, in Inches.	One in	Horizontal Measure, Hypothenuse being 1.	Vertical Measure, Hypothenuse being 1.	Deduct Links per Chain.	Gravity due to Incline per Ton, in Pounds.	Square Yards per Acre.
46	37·27	·96	·69466	·71934	30·53	1611·32	6967·43
47	38·60	·93	·68200	·73135	31·80	1638·22	7096·77
48	39·98	·90	·66913	·74314	33·09	1664·63	7233·27
49	41·41	·87	·65606	·75471	34·39	1690·55	7377·37
50	42·90	·84	·64279	·76604	35·72	1715·92	7529·67
51	44·46	·81	·62932	·77715	37·07	1740·81	It is obviously unnecessary to give this bove (about) 50-degrees.
52	46·07	·75	·61566	·78801	38·43	1765·14	
53	47·77	·73	·60181	·79864	39·82	1788·95	
54	49·54	·70	·58778	·80902	41·22	1812·20	
55	51·41	·67	·57358	·81915	42·64	1834·89	
56	53·36	·65	·55919	·82904	44·08	1857·04	
57	55·44	·62	·54464	·83867	45·54	1878·62	
58	57·61	·62	·52992	·84805	47·01	1899·63	
59	59·92	·60	·51504	·85717	48·50	1920·06	
60	62·35	·58	·5	·86602	50·00	1939·88	
61	64·94	·55	·48481	·87462	51·52	1959·14	
62	67·69	·53	·46947	·88295	53·05	1977·80	
63	70·65	·51	·45399	·89101	54·60	1995·86	
64	73·80	·49	·43837	·89879	56·16	2013·28	
65	77·20	·47	·42262	·90631	57·74	2030·13	
66	80·86	·45	·40674	·91355	59·33	2046·35	
67	84·81	·42	·39073	·92050	60·93	2061·92	
68	89·10	·40	·37461	·92718	62·54	2076·88	
69	93·77	·88	·35837	·93358	64·16	2091·21	
70	98·91	·36	·34202	·93969	65·80	2104·90	
71	104·53	·34	·32557	·94552	67·44	2117·96	
72	110·80	·32	·30902	·95106	69·10	2130·37	
73	117·73	·31	·29237	·95630	70·76	2140·11	
74	125·56	·29	·27564	·96126	72·44	2153·22	
75	134·37	·27	·25882	·96593	74·12	2163·68	
76	144·40	·25	·24192	·97030	75·81	2173·47	
77	155·90	·23	·22495	·97437	77·50	2182·58	
78	169·36	·21	·20791	·97815	79·21	2191·05	
79	185·20	·19	·19081	·98163	80·92	2198·85	
80	204·10	·18	·17365	·98481	82·63	2205·97	
81	227·34	·16	·15643	·98769	84·36	2212·42	
82	256·11	·14	·13917	·99027	86·08	2218·20	
83	293·13	·12	·12187	·99253	87·81	2223·26	
84	342·60	·10	·10453	·99452	89·55	2227·72	
85	411·27	·09	·08716	·99619	91·28	2231·46	
86	514·52	·07	·06976	·99756	93·02	2234·53	
87	—	—	·05234	·99863	94·77	2236·93	
88	—	—	·03490	·99939	96·51	2238·63	
89	—	—	·01745	·99985	98·25	2239·66	

We will take for our first illustration the case sketched in fig. 350, and we will suppose A to be the pit shaft or starting-point, and B the place where the dial is first fixed. After the dial is firmly fixed and adjusted with spirit levels, the south sight is turned in the direction of the shaft at point A, the north sight being looked through until the south sight cuts a lighted candle or lamp held in the middle of the shaft at A, and when the needle is at rest, entry is made in a book of the number of degrees pointed to by the north end of the needle. Suppose the bearing from A to B is N 10 E, this would be north-east 10 degs. The dial is then turned, and looking through the sight S until the sight N cuts a light at C, the needle again coming to rest, the bearing is read, which we will suppose to be N 5 E; this would be north-east 5 degs., or 5 degs. from the last bearing, and would turn the roadway a little to the left. These two bearings being properly entered in the book, the next thing to be done is to take the measurements from A to B and from B to C. We will suppose the measurement from A to B to be 60 yards; the same is entered in a book near the first bearing; the distance from B to C is then measured, which we will suppose to be 45 yards; this is also entered in the book near the second bearing. The dial is taken up and again fixed and adjusted as before at D. The instrument is turned, and looking through the sight N until the sight S cuts a light held at C, the number of degrees the north end of the needle points to is read off, care being taken not to read while the needle is vibrating. We will suppose this bearing to be N 2 E; this would be north-east 2 degs. The roadway again turns a little to

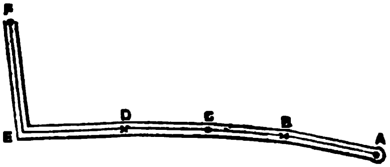


Fig. 350.

left. The dial is now turned, and the reading again noted when, looking through the sight S, the sight N cuts a light held at E. This operation must be strictly adhered to throughout the survey; that is to say, the sight N when going forward must be kept next the working face, and the sight S when looking towards the pit, or in other words, the surveyor must always look through the sight S at objects which convey him from the pit into the workings, and so on, sight after sight, until he comes to the working face; but in taking a back sight, as in the two cases previously mentioned—looking at objects in the direction of the pit—he must look through the sight S, that is, the sight N always in the direction in which he is proceeding. The next thing to be done is to measure the distance from C to D, which we will suppose to be 50 yards; this must be entered in the book near the third bearing, and the distance from D to E being measured, which we will suppose to be 60 yards, is also entered near the fourth bearing, which is N 5 W, or 5 degs. north-west, or 7 degs. west from the last bearing—turning the roadway again a little farther to the left. The dial is again taken up and fixed and adjusted as before at F, and the dial turned round. Looking through the sight N until the sight S cuts a light held at E, the bearing is read off as soon as the needle comes to a standstill. We will suppose that the north end of the needle in this case points to N 85 E; this would be 85 degs. north-east, or an angle of 90 degs. from the last bearing, or as it is termed in the underground workings, one roadway being driven at right angles to the other. This bearing having been duly entered in the book, the next thing to be done is to measure the distance from E to F, which we will suppose to be 70 yards; this is also entered in like manner near the last or fifth bearing. These five bearings having been plotted and the measurements given to each bearing, the underground roadway will be something similar in form to the sketch, fig. 350. We will take for our second illustration the case represented in fig. 351. Let us suppose that there are a pair of levels or roadways driven on each side of the two pits, and that other openings or cut-throughs are driven at suitable distances to connect the two levels together for the purposes of ventilation; the dial must first be placed at A, and being adjusted as before described, the sight S must be turned round until it cuts a light held at the pit, H, looking through the sight, N.

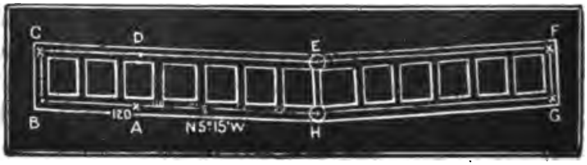


Fig. 351.

In this illustration we will give degrees and minutes, so that the student may be familiarised with more precise measurements. We will suppose the first bearing to be N 5 degs. 15 min. W; this would be north-west 5 degs. 15 min., which must be entered in the book. The distance is then measured from A to H, which we will suppose to be 120 yards; this must also be entered near the previous bearing. In this measurement there will be four roadways or openings to the right; these must be carefully measured off and entered in the book. The dial must now be turned round, looking through the sight S until the sight N cuts a light held at B. This bearing should be read off and entered; we will suppose it to be N 6 degs. 12 min. W. The distance is then measured from A to B—suppose it to be 80 yards—care being taken to read off all openings or cut-throughs on either the right or left. It is usual when the dial is fixed to take all the bearings first that can be taken at the one fixing and to enter them in the book, afterwards measuring the distance of each and entering it near its own bearing. The dial is again taken up and fixed at C, and turning it round and looking through the sight N until the sight S cuts a light held at B, the bearing is read off from the north end of the needle, this being a back sight. The sight N must always be kept in the direction in which the surveyor is proceeding, and the sight S in the direction of the ground he has just worked over. We will suppose this bearing to be N 85 degs. 35 min. E. This having been duly recorded, the dial is turned round, and looking through the sight S until the sight N cuts a light held at D, the bearing should be read off as before; we will suppose it to be S 6 degs. 12 min. E. The distance from C to B is then measured, being 35 yards, and entered in the book near its own bearing. Next, the distance from C to D is ascertained to be 80 yards. Care should here also be taken to measure off all openings right and left. Let us suppose that it is convenient that the dial should next be fixed in the centre of the pit at E. If this were found inconvenient the instrument would have to be fixed at some suitable place between D and E, the latter point being *per se* the most suitable, as a bearing could be taken between the two pits, which would serve as a tie or check to the survey when the work came to be plotted. The dial being again fixed and adjusted, it should be turned round, and looking through the sight N until the sight S cuts a light held at D, this bearing should be read off and entered in the book. Suppose it to be S 5 degs. 15 min. E. The dial is again turned round, and looking through the sight S until the sight N cuts a light held at F, this bearing must be read off—say, S 7 degs. 45 min. E—and duly entered. The dial must now again be turned round, and looking through the sight N until the sight S cuts a light held in the centre of the other pit, H, the bearing can be read off and entered in the book, say N 85 degs. 35 min. E. The distance of the last three bearings must now be measured, and each measurement entered in the book near its own bearing. The distance from E to D is 120 yards, from E to F 160 yards, and from E to H 35 yards. The dial should again be removed and fixed at G, and then turning it round and looking through the sight N until the sight S cuts a light held at F, the bearing must be read off and entered—S 85 degs. 35 min. W. The dial should now be again turned round, and looking through the sight S until the sight N cuts a light held at the centre of the pit, H, and this bearing read off and entered—N 7 degs. 45 min. W. If the survey had been commenced at the other side of the pit, this last bearing would have read *vice versa*, that is, S 7 degs. 45 min. E. The distances of these two bearings are measured from G to F, and ascertained to be, say 35 yards, and from G to H 160 yards.

If the dial has been properly fixed and adjusted in each case, all material that would have any attracting influence upon the needle removed to a sufficient distance, and the bearings and measurements correctly read off and booked, and if the survey has been accurately plotted on the plan, it will correspond with fig. 351. If all the bearings and measurements do not tie in or connect, there must have been a misreading either of the bearings or the measurements, or the needle must have been attracted from its proper bearing. In this case a portion, if not the whole of the survey, will have to be gone through again.

778. Describe the method of using the fast needle in surveying.

To survey with a fast needle the vernier is generally adjusted to 0 deg. before every sight, this being the surest means of avoiding mistakes. After levelling the instrument, a sight is taken of the first light, the bottom plate is unclamped and the sights of the instrument turned till a sight is taken of the second light. The included angle is then read with the vernier and booked, and distance chained. The same operation is repeated for the second and third lights. The first sight is also carefully taken with the loose needle, to assure the plotting of the survey in the right position.

779. In plotting a theodolite and fast needle survey, how would you bring the angles to bearings?

To plot a theodolite and fast needle survey, I would in the first place reduce all the angles to an original base line—that is, if the angle is under 180 degs., I should subtract the deficiency from the previous one, and if over 180 degs., add the excess to the previous one.

780. Give a detailed description of plotting a loose needle survey.

When the underground survey or dialling is completed, the next thing to be done is to lay the workings on a plan; care being exercised that all the bearings, measurements, and the dip of the mine in the several places have been accurately taken. The first thing to be done is to make a mark on the plan similar to the letter O to represent the pit. This should be placed as near as possible to the centre of the plan, as usually the workings

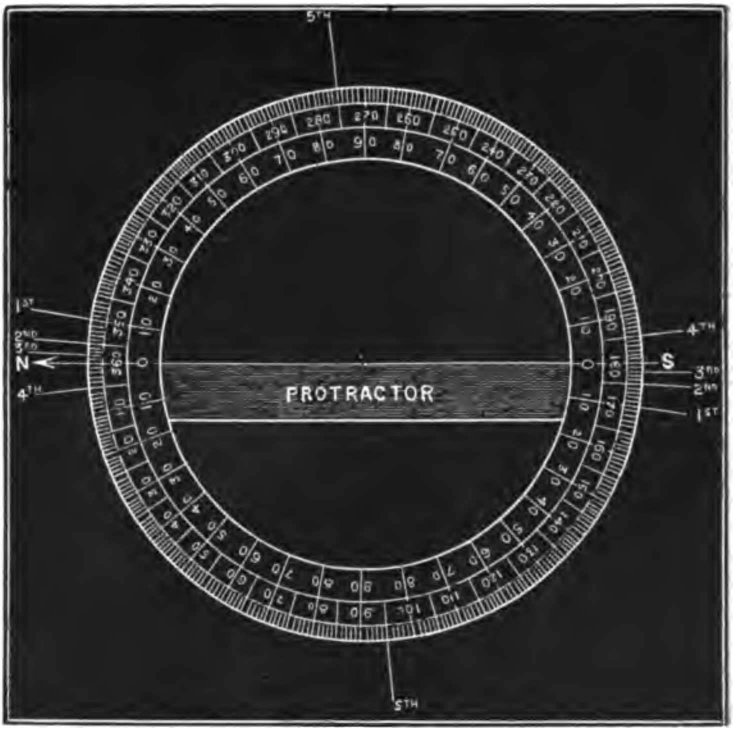


Fig. 352.

are carried in every direction from the pit. Every plan must have either the true north line or magnetic meridian drawn upon it. When the true north line is drawn, the protractor should be laid upon it (fig. 352). It will be seen that there are two rows of figures on the protractor which correspond exactly with the two rows of figures on the dial, except that the figures on the dial read one way and those on the protractor read the other; that is to say, if the dial should read off to the right, the protractor reads off to the left. This will be found to be the case with most dials now manufactured, but it makes no difference in the plotting, as whatever way the dial reads the same must be pricked off on the protractor. Suppose, for an illustration, that the underground workings represented in fig. 350 have to be plotted on plan. It will be found by referring to a previous paragraph that the first bearing is N 10 E; this is pricked off round the protractor, and marked "1st"; the second bearing N 5 E, is then pricked off and marked "2nd"; the third bearing, which is N 2 E, is pricked off in the same manner and marked "3rd"; the fourth bearing, which is N 5 W, is also pricked off and marked "4th"; and the fifth and last bearing, which is N 85 E, is similarly pricked off and marked "5th." It will be seen that each of these bearings is pricked off and marked in two places, one being on the opposite side of the protractor to the other—that is, the first bearing which is pricked off at north-east 10 degs. is also pricked off at south-west. When all the bearings are marked and pricked off in this manner, the protractor is taken up and a line drawn from the bearing first pricked off on the side of the protractor to that pricked off on the opposite side; this line is then carried parallel to the pit; another line is drawn parallel to this which will represent A to B (fig. 350). For making lines of this sort a parallel ruler is used, which enables a line parallel to any line of the plan to be drawn upon any other portion. The length of this bearing, A B, which is 60 yards, is then measured by an ivory scale. There is a great variety of scales, for all plans are not made on the same proportions, and whatever may be the proportion to which the plan is drawn, a corresponding scale will be required with which to measure the various distances and find the exact positions of the details of the plan. The figure No. 350 is plotted to a scale of 40 yards to the inch—that is, each inch on the ivory scale is divided into forty equal parts, and each part represents a yard in the underground workings as plotted, on plan. A line being drawn and measured off correctly to represent the first bearing, another line is drawn from the second bearing pricked off on the one side of the protractor to that on the other. This line is made parallel to B; another line is drawn from B to C, and the distance measured along it, which will be found to be 45 yards. Another line is then drawn parallel from the third bearing pricked off on the one side of the protractor to that on the other side; this is carried parallel to C, and another line from C to D; the distance is measured, and found in this case to be 50 yards. The same thing is done in regard to the fourth bearing, and a line drawn parallel to the line between the two pin marks on either side of the protractor; this will represent the line drawn from D to E. The measurement, 60 yards, is then marked off, and another line drawn from the fifth bearing pricked off on one side of the protractor to that on the other side, and is parallel to E. Another line, parallel to this, is then drawn from E to F, the distance being 70 yards, and so the work proceeds until the whole is plotted, the plotting and measuring of each bearing being made from the one previously plotted, unless some of the bearings are on the opposite side of the pit, or in other parts of the underground workings. If there are workings on each side of the pit they must be plotted as above described, one part of the plotting commencing on one side of the pit and the other part on the other side, and so on, however extensive the survey may be; in other words, the bearings must always be taken from the end of those previously plotted. If bearings have to be plotted from workings on other parts of the plan they are commenced from the bearings or workings last plotted, in their own parts respectively. All plottings should first be done with pencil and afterwards traced with Indian ink, so that any error in laying down the detail might easily be erased without injury to the plan.

781. How are angles usually expressed ?

Angles are usually espressed by three letters, that placed at the angular point being always mentioned second in quoting the letters which indicate the angle. In figs. 353 and 354, E is the angle of A E D or B E D.

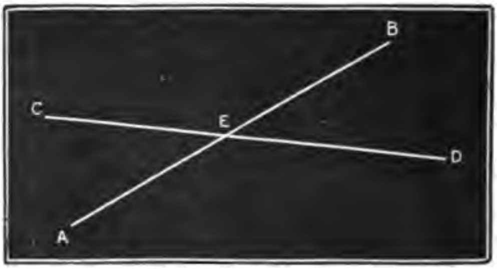


Fig. 353,

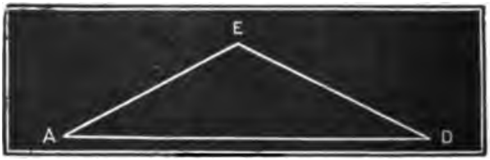


Fig. 354.

782. What is a right angle ?

When a straight line stands upon another straight line making the adjacent angles equal, each of these angles is called a right angle, A B C (fig. 355).

783. What is an acute angle ?

An acute angle is one which is less than a right angle, as A B D (fig. 355).

784. What is an obtuse angle ?

An obtuse angle is one which is greater than a right angle or more than 90 degs., as D B E (fig. 355).

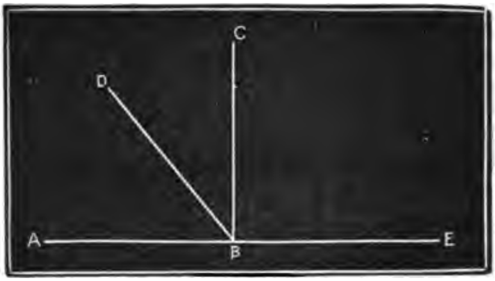


Fig. 355.

785. The two sides of a right-angled triangle being given, how would you find the third ?

See fig. 356. *Rule* 1.—To find the square of the base add the square of the perpendicular, the square root of the sum will be the hypothenuse.

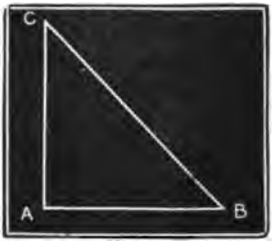


Fig. 356.

Rule 2.—Multiply the sum of the hypothenuse and one side and their difference, and the square of that product will be the other side.

Example 1.—The base A B = 320 and perpendicular B C = 246 being given, find the length of the hypothenuse A C.

Answer:—$320^2 + 246^2 = \sqrt{}162,916 = 403$, the hypothenuse A C.

Example 2.—The base A B = 320 and hypothenuse A C = 403 being given, find the length of the perpendicular B C.

Answer:—403 + 320 × 83 = $\sqrt{60,009}$ = 245.

786. How is land measured?

In measuring land the area or superficial contents is always expressed in acres, or in acres, roods and perches; each acre containing 4 roods, and each rood 40 perches. Land is usually measured with a statute chain, called Gunter's chain, of 4 poles or 22 yards in length, consisting of 100 equal links, each link being $\frac{22}{100}$ of a yard long, or $\frac{66}{100}$ of a foot, or 7·92 in. Ten square chains, or 10 chains in length and one in breadth, make an acre, or 4,840 square yards, or 160 square poles, or 100,000 square links. The lengths of lines measured with the chain are generally set down in links as integers, every chain being 100 links in length. Therefore, when the content is found, it will be in square links, and as 100,000 square links make an acre, it will be necessary to cut off five of the figures on the right hand for decimals, and the rest will be acres. The decimals are reduced to roods by multiplying by 4, and cutting off five figures as before for decimals, and the decimal part is reduced to perches by multiplying by 40 and cutting off five figures from the product. As an example, suppose the length of a rectangular piece of ground to be 1,260 links, and its breadth 1,540, the number of acres, roods and perches it contains will be:—1,260 × 1,540 = 19·40400 acres × 4 = 1·61600 roods × 40 = 24·64000 perches, which reads thus:—19 acres, 1 rood and 24½ perches. A statute perch is 5½ yards, but the Irish plantation perch is 7 yards; hence the length of a plantation link is 10·08 in.

787. Give a rule to find the area of a triangle.

Rule.—Multiply the base by the perpendicular, and divide the product by 2 for the area.

Example: The base of a triangle is 76·5 chains, and the perpendicular 92·2 chains; what is its area?

Answer.—$\frac{76{\cdot}5 \times 92{\cdot}2}{2}$ = 3,526·65 square chains, the area.

788. The base of a triangular field is 1,276 links, and its perpendicular 976 links; how many acres are there in it?

Answer.—$\frac{1,276 \times 976}{2} = 6{\cdot}22688$ acres × 4 = ·90752 × 40 = 36·30080 perches; thus, there are 6 acres, 0 roods, 36·30080 perches.

789. Having the three sides of any triangle given, how would you find its area?

Rule.—From half the sum of the three sides subtract each side separately; then multiply the half-sum and the three remainders together, and the square root of the last product will be the area of the triangle.

Example.—Suppose the side A B of a triangle (fig. 357) measure 9·2 yards, and the side B C 7·5 yards, and A C 5·5 what is the area of the triangle?

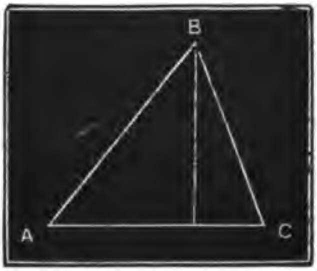


Fig. 357.

$$\begin{array}{lr} & 9{\cdot}2 \\ & 7{\cdot}5 \\ & 5{\cdot}5 \\ \hline \text{Sum......} & 22{\cdot}2 \\ \hline \end{array}$$

$$\text{Half-sum}\ \left.\begin{array}{l} 11{\cdot}1 - 9{\cdot}2 = 1{\cdot}9 \\ 11{\cdot}1 - 7{\cdot}5 = 3{\cdot}6 \\ 11{\cdot}1 - 5{\cdot}5 = 5{\cdot}6 \end{array}\right\} \text{Then } \sqrt{}(11{\cdot}1 \times 1{\cdot}9 \times 3{\cdot}6 \times 5{\cdot}6) = \sqrt{}425{\cdot}1744 = 20{\cdot}619 \text{ area.}$$

790. Give a rule to find the area of a trapezium

Rule.—Divide the trapezium into two triangles, by joining two of its opposite angles, find the area of each triangle, and the sum of both areas will give the area of the trapezium. Or, draw two perpendiculars from the opposite angles to the diagonal, then multiply the sum of these perpendiculars by the diagonal, and half the product will give the area.

791. In the trapezium A B C D, fig. 358, the diagonal A C, is 100 yards, the perpendicular, D E, 35, and B F 30; what is its area?

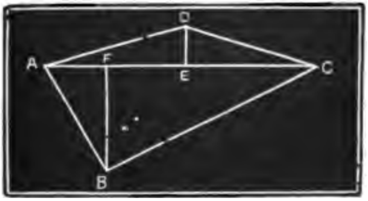


Fig. 358.

D E = 35, B F = 30, = 65 × 100 = 6,500 ÷ 2 = 3,250 the area.

The following additional examples under this head will be of service to students:—

(1.) Find the area of a triangular field having two sides and the included angle—say, A B = 5 chains 20 links, and A C = 8 chains 40 links, angle B A C is 60°.

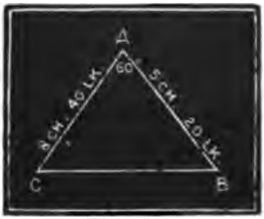


Fig. 359.

$$\text{Area of } A\,B\,C = \frac{A\,C \times A\,B \times \sin.\ B\,A\,C}{2} =$$

$$\frac{840 \times 520 \times \sin.\ 60^\circ}{2} = \frac{840 \times 520 \times \frac{\sqrt{3}}{2}}{2}$$

$= 420 \times 260 \times \sqrt{3} = 420 \times 260 \times 1{\cdot}73205$

$= 189{,}139{\cdot}86$ sq. links = 1 acre, 3 roods, 22·623776 perches.

In the above solution the natural sine of angle B A C is used.

The problem may be solved by logarithms, the method which I should advise the student at once to adopt on account of its general application and utility.

Log. area of A B C = log. A C + log. A B + L sin. B A C − log. 2 − 10 = log. 840 + log. 520 + L sin. 60 − log. 2 − 10 = + 2·924279 + 2·716003 + 9·937531 − 0·301030 − 10·000000 = 5·276783 = log. 189,139·86.

Therefore area of A B C = 1 acre 3 roods, 22·623776 as above.

(2.) Find the area of a triangular field where only one side can be measured, but where the angles can be observed.

Let side A B be 6 chains, angle A be 60°, angle B 90°, and angle C 30°.

$$\text{Area of } A\ B\ C = \frac{A\ B^2 \sin.\ B\ A\ C \sin.\ A\ B\ C}{2 \sin.\ A\ C\ B} =$$

$$\frac{6^2 \times \sin.\ 60^\circ \times \sin.\ 90^\circ}{2 \sin.\ 30^\circ} = \frac{6^2 \times \frac{\sqrt{3}}{2} \times 1}{2 \times \frac{1}{2}} = 36 \times \frac{\sqrt{3}}{2}$$

= 18 $\sqrt{3}$ square chains = 3 acres, 0 roods, 18·8304 perches; or log. area of A B C = 2 log. A B + L sin. 60 + L sin. 90 − log. 2 − L sin. 30 − 10, as above.

(3.) How is it possible to measure across a river?

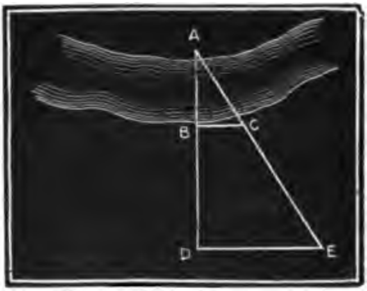


Fig. 360.

Take any object on the opposite bank, as A (fig. 360).

In a direct line measure B D. At B and D set off perpendiculars, B C and D E, at measured lengths, so that A C E shall be in a straight line. Then the distance across the river, or $A\,B = \frac{B\,D \times B\,C}{D\,E - B\,C}$.

Let B C = 50 links. B D = 1 chain, and D E = 80 links.

$$\text{Then } A\,B = \frac{100 \times 50}{80 - 50} = \frac{5000}{30} = 166\tfrac{2}{3} \text{ links.}$$

Or, measure a line B C (fig. 361) along side of river and

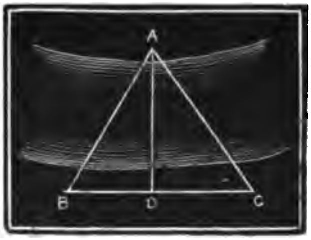


Fig. 361.

observe angles at B and C. Then angle A is known, since angle A = 180 − (B + C). Therefore, $A\,B = \frac{B\,C \sin. C}{\sin. A}$.

But the perpendicular distance A D = A B sin. B = $\frac{B\,C \sin. B \sin. C}{\sin. A}$. Let A B = 2 chains, ∠ B = 60° ∠ C = 30°.

Then ∠ A = 90°.

$$\text{Therefore, } A\,D = \frac{2 \times \sin. 60^\circ \times \sin. 30^\circ}{\sin. 90^\circ} = \frac{2 \times \frac{\sqrt{3}}{2} \times \frac{1}{2}}{1}$$

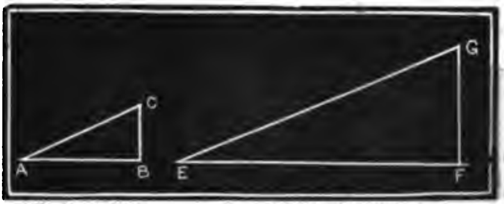
$$= \frac{\sqrt{3}}{2} \text{ chains} = \frac{1{\cdot}73205}{2} = {\cdot}866 \text{ chains} = 86{\cdot}6 \text{ links.}$$

(4.) Find the height of a chimney stack, having given the length of the shadow of the chimney and the height of a stick with length of its shadow.

In fig. 362 A B : E F :: B C : G F. Therefore, G F = $\frac{E\,F \times B\,C}{A\,B} = \frac{\text{shadow of chimney} \times \text{height of stick}}{\text{shadow of stick}}$.

Let A B = 8 ft., B C = 6 ft., and E F = 64 ft.

$$\text{Then } G F = \frac{64 \times 6}{8} = 48 \text{ ft.}$$



Shadow of Stick. Shadow of Chimney.

Fig. 362.

(5.) Find the height of an object having the horizontal base line and the angle; the object subtends at end of base line being stated.

In fig. 363, height B C = A B, tangent B A C.

(1.) Let A B = 60 ft. and ∠ B A C = 45°.

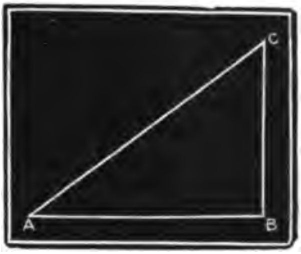


Fig. 363.

Then B C = 60 × tan. 45 = 60 × 1 = 60 ft.

(2.) Let A B = 303 ft., and angleB A C = 30°.

Then B C = A B tan. B A C = 303 × tan. 30° ft. + 303 × $\frac{1}{\sqrt{3}}$ = 101 × $\sqrt{3}$ ft. = 101 × 1·73205 ft. = 174·93705 ft.

(6.) Find the height of an inaccessible object, such as a tower, a chimney, &c.

Measure in straight line (fig. 364), B A; observe the angles D B C and D A C. From this data the distance, B C, as well as the height, D C, may be ascertained.

Angle $A\ D\ B = \angle\ D\ B\ C - \angle\ D\ A\ C.$

Therefore $B\,D = \frac{A\,B \text{ sin. } D\,A\,C}{\text{sin. } A\,D\,B}$. Therefore—

Height $D\,C = B\,D \text{ sin. } D\,B\,C = \frac{A\,B \text{ sin. } D\,A\,C \text{ sin. } D\,B\,C}{\text{sin. } A\,D\,B}$

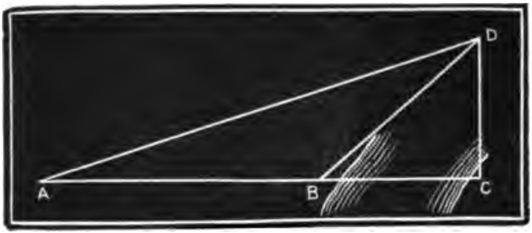


Fig. 364.

Therefore breadth $B\,C = \frac{A\,B \text{ sin. } D\,A\,C \text{ cos. } D\,B\,C}{\text{sin. } A\,D\,B}$.

Let $\angle\ D\,B\,C = 60°$, $D\,A\,C = 30°$ and $A\,B = 100$ ft., find D C and B C.

Hence $\angle\ A\,D\,B = 60 - 30 = 30°$.

Therefore height of $D\,C = \frac{100 \times \text{sin. } 30 \times \text{sin. } 60°}{\text{sin. } 30}$

$= 100 \times \frac{\sqrt{3}}{2} = 50 \times 1{\cdot}73205 = 86{\cdot}6025$ ft.

Breadth of $B\,C = \frac{100 \times \text{sin. } 30° \times \text{cos. } 60°}{\text{sin. } 30°} = 100\ 60°$

$\text{cos.} = 100 \times \frac{1}{2} = 50$ ft.

(7). The angle of batter of a chimney stack is given, and it is required to determine the height of stack.

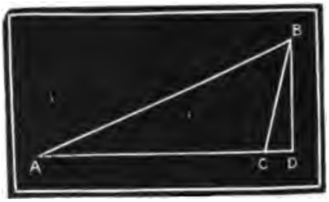


Fig 365.

Let angle B C D (fig. 365), be the given batter of chimney. Measure a distance C A perpendicular to the side of stack. Observe angle B A D. Then we have angle A B C = angle B C D − angle B A C = Φ.

$$\therefore AB = \frac{AC \times \sin. BCD}{\sin. \Phi}.$$

Therefore, height required B D = A B sin. B A D = $\frac{AC \sin. BCD \sin. BAD}{\sin. \Phi}$ or

Log. B D = log. A C + L sin. B C D + L sin. B A D − L sin. Φ − 10.

Let angle B C D = 75°, and angle B A C = 30°. A C = 100 ft., find B D.

Therefore, height required B D = $\frac{100 \times \sin. 75^\circ \times \sin. 30^\circ}{\sin. (75^\circ - 30^\circ)}$ =

$$\frac{100 \times \sin. 75^\circ \times \sin. 30^\circ}{\sin. 45^\circ} = \frac{100 \times \frac{\sqrt{3}+1}{2\sqrt{2}} \times \frac{1}{2}}{\frac{1}{\sqrt{2}}} =$$

$25 \times (\sqrt{3} + 1) = 25 \times 2{\cdot}73205 = 68{\cdot}30125$ ft.

NOTE:—

$\text{Sin. } 30^\circ = \frac{1}{2}$ $\cos. 30^\circ = \frac{\sqrt{3}}{2}$ $\tan. 30^\circ = \frac{1}{\sqrt{3}}$

$\text{Sin. } 45^\circ = \frac{1}{\sqrt{2}}$ $\cos. 45^\circ = \frac{1}{\sqrt{2}}$ $\tan. 45^\circ = 1$

$\text{Sin. } 60 = \frac{\sqrt{3}}{2}$ $\cos. 60^\circ = \frac{1}{2}$ $\tan. 60^\circ = \sqrt{3}$

$\text{Sin. } 75 = \frac{\sqrt{3}+1}{2\sqrt{2}}$ $\cos. 75^\circ = \frac{\sqrt{3}-1}{2\sqrt{2}}$ $\tan. 75^\circ = 2 + \sqrt{3}$

$\text{Sin. } 90 = 1$ $\cos. 90^\circ = 0$ $\tan. 90^\circ = \infty$

792. What is the variation of the magnetic meridian from true north ?

The magnetic meridian was, at the commencement of the present year (1889) about 17 degs. 40 min. to the west of true north, and this difference diminishes yearly. The maximum declination occurred in the year 1818, at which time it was 24 degs. 41 min. to the west of true north. The declination at that time decreased at the rate of only 1 min. per year.

793. Describe the method of finding true north.

To find true north, the usual method is to erect a thin vertical rod on a level drawing board, and observe shortly before mid-day the end of the shadow caused by the rod. From this point, and with the rod as a centre, describe an arc of a circle, and note when the end of the shadow again touches it; midway between these two points make a mark, and a line drawn from the rod to this mark will represent the direction of true north. This line may be extended out to some length, and pegs put in, so that the variation of the compass may be observed at any time.

794. Give a table for reducing Cheshire acres, roods and perches into yards.

The following is a good table for the purpose:—

Acres.	Yards.	Perches.	Yards.	Perches.	Yards.
1	10,240	1	64	21	1,344
2	20,480	2	128	22	1,408
3	30,720	3	192	23	1,472
4	40,960	4	256	24	1,536
5	51,200	5	320	25	1,600
6	61,440	6	384	26	1,664
7	71,680	7	448	27	1,728
8	81,920	8	512	28	1,792
9	92,160	9	576	29	1,856
10	102,400	10	640	30	1,920
11	112,640	11	704	31	1,984
12	122,880	12	768	32	2,048
13	133,120	13	832	33	2,112
14	143,360	14	896	34	2,176
15	153,600	15	960	35	2,240
16	163,840	16	1,024	36	2,304
17	174,080	17	1,088	37	2,368
18	184,320	18	1,152	38	2,432
19	194,560	19	1,216	39	2,496
20	204,800	20	1,280		

Roods.	Yards.
1	2,560
2	5,120
3	7,680

795. Describe the method by which you would ascertain the quantity of coal wrought in acres per foot thick, after the work has been plotted on plan, supposing the seam to have been worked on the longwall system.

Usually the wall face is zigzag or crooked, consequently it would form a crooked-sided figure. We will suppose fig. 366 to be the area to be measured. First measure the four dotted straight lines A, B, C, D, which would cut all the irregular places off, then measure the diagonal line A C and the two perpendiculars E D and F B; then form a trapezium similar to fig. 358. The area can be found by the same rule as previously given for finding the area of a triangle, the figure being divided into two triangles. The area being found, multiply the product by the number of feet the seam is in thickness, and this will give the number of acres, roods and perches.

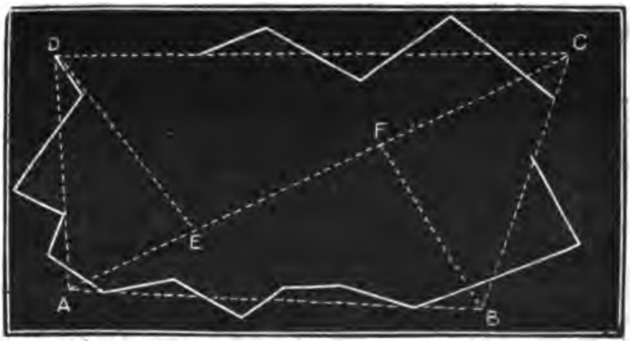


Fig. 366.

796. How is Indian ink prepared for use?

It is prepared for use by rubbing with water in one of a nest of saucers, for which there should be a good-fitting cover. The saucer ought to be quite smooth inside, so as not to abrade the ink, which, when mixed to the required blackness, should immediately be covered to preserve it from such particles of dust as are constantly floating about a room. In order to supply the pen with ink it will be found necessary in the first instance to moisten the nibs by placing them between the lips or by other means, when, if the point of the pen be placed in the ink, the fluid will rise by capillary attraction between the nibs; the ink adhering to the exterior parts of the pen must be removed by drawing them over a piece of blotting paper. This method of filling the pen with ink will be found much cleaner and more convenient than supplying the ink with a brush. Indian ink, after it has become thick or dried up, may be renewed as follows:—Always keep at hand a piece of india-rubber about the size and shape of two joints of the forefinger of the hand. When the ink is dried up in the saucer, but not in flakes, it may be reduced to an impalpable paste by grinding it with the india-rubber, the end whereof has been previously wetted, a drop of water being added from time to time as the rubbing proceeds. This operation improves the quality of the ink by reducing the gritty particles. The water must not be allowed to drop into the saucer at the commencement of the operation, as that might cause the ink to leave the saucer in flakes, which would have to be removed and the saucer washed out.

979. How are different materials shown on plans, &c., by colour?

The following table shows the colours most employed:—

Carmine or crimson lake...	For brickwork in plan or section to be executed.
Prussian blue	Flintwork, lead, or parts of brickwork to be removed by alterations.
Venetian red	Brickwork in elevation.
Violet carmine...	Granite.
Raw sienna	English timber (not oak).
Burnt sienna	Oak, teak.
Indian yellow	Fir timber.
Indian red	Mahogany.
Sepia	Concrete works or stone.
Burnt umber	Clay or earth.

Payne's grey or neutral tint	Cast iron, rough wrought iron.
Prussian blue (light)	Wrought iron.
Dark cadmium	Gun-metal.
Gamboge	Brass.
Indigo	Wrought iron (bright).
Indigo (with a little lake)	Steel (bright).
Hooker's green	Meadow land.
Cobalt blue	Sky effects.

In colouring plans of estates, the colours that appear natural are mostly adopted, which may be produced by combining the above. Elevations and perspective drawings are also represented in natural colours, the primitive colours being mixed and varied at the judgment of the draughtsman. The following are a few of the principal combinations of colours:—

Red + Yellow = Orange.
Red + Blue = Purple.
Blue + Yellow = Green.
Orange + Purple = Brown.
Orange + Green = Grey.
Purple + Green = Broken Green.

ERRATA.

In table, page 48, combining weight of ethyl ether should be 73·84.

In table, page 73, last line, read 91·4400 instead of 90·4400.

Page 348, 14th line, read 12·97 instead of 12·35.

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